



2000-03-01

Screen dispositions of Naval Task Forces against Anti-Ship Missiles

Aydin, Erhan.

Monterey, California. Naval Postgraduate School

<http://hdl.handle.net/10945/7785>



Calhoun is a project of the Dudley Knox Library at NPS, furthering the precepts and goals of open government and government transparency. All information contained herein has been approved for release by the NPS Public Affairs Officer.

**Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943**

<http://www.nps.edu/library>

NPS ARCHIVE
2000.03
AYDIN, E.

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCH
MONTEREY CA 93943-5111

NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA



THESIS

SCREEN DISPOSITIONS OF NAVAL TASK FORCES AGAINST ANTI-SHIP MISSILES

By

Erhan Aydin

March 2000

Thesis Advisor:
Second Reader:

Arnold H. Buss
Douglas J. Mackinnon

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

| | | |
|---|------------------------------|---|
| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE March 2000 | 3. REPORT TYPE AND DATES COVERED Master's Thesis |
| 4. TITLE AND SUBTITLE Screen Dispositions of Naval Task Forces Against Anti-Ship Missiles | | 5. FUNDING NUMBERS |
| 6. AUTHOR(S) Aydin, Erhan | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000 | | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSORING / MONITORING AGENCY REPORT NUMBER |

11. SUPPLEMENTARY NOTES

The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

| | |
|---|------------------------|
| 12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. | 12b. DISTRIBUTION CODE |
|---|------------------------|

13. ABSTRACT (maximum 200 words)

Ship defense in convoy operations against Anti-Surface Missiles (ASM) has been an important aspect of Naval Warfare for the last two decades. Countries in a state of conflict often conduct threatening operations in their own territories in order to slow or stop the enemy merchant ship traffic through the straits or littoral waters. Such littoral scenarios, the quantity and capability of ASM's in non-NATO countries pose a significant threat to the safe operation of the NATO forces in the waters off of potentially hostile shores. In these operations the goals of the tactical commander are to design an optimal reaction platform (formation) and to determine an optimal strategy that will help him in multi-threat encounters. The scope and design in most anti-air warfare studies have been limited to evaluating the effectiveness of detecting sensors and weapon systems in a regular screen formation. The proposed model's (Disposition Mission Model – DMM) characterization, however, is based on how to perform an effective, defensive disposition from a task force. In DMM we focus on usage of a graphical user interface and provide a user-friendly environment for analyzing new tactics in screen formations. The model, with its user interface, allows the user to build and run a convoy simulation, and see the results comparatively on the same interface. The analysis using this model has yielded significant insights towards the defense of a convoy by way of regression methods. It has been seen that positioning the escort ships within the threat sector reduces the damage on the HVU and also balances the defensive load of each defense ship for the incoming missiles. The model, with its graphical interface and simulation components, provides an initial approach for future analysts, not only in anti-air warfare defense of screen formations, but also in the areas of anti-surface and anti-submarine warfare.

| | | | |
|--|--|---|----------------------------------|
| 14. SUBJECT TERMS Littoral Arena, Disposition, Tactics, Simulation, Graphical User Interface, Swing | | 15. NUMBER OF PAGES | |
| | | 16. PRICE CODE | |
| 17. SECURITY CLASSIFICATION OF REPORT Unclassified | 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified | 20. LIMITATION OF ABSTRACT UL |

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18 298-102

Approved for public release; distribution is unlimited

**SCREEN DISPOSITIONS OF NAVAL TASK FORCES AGAINST
ANTI-SHIP MISSILES**

Erhan Aydin
Lieutenant Junior Grade, Turkish Navy
B.S., Turkish Naval Academy, 1994

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March 2000

ABSTRACT

Ship defense in convoy operations against Anti-Surface Missiles (ASM) has been an important aspect of Naval Warfare for the last two decades. Countries in a state of conflict often conduct threatening operations in their own territories in order to slow or stop the enemy merchant ship traffic through the straits or littoral waters. Such littoral scenarios, the quantity and capability of ASM's in non-NATO countries pose a significant threat to the safe operation of the NATO forces in the waters off of potentially hostile shores. In these operations the goals of the tactical commander are to design an optimal reaction platform (formation) and to determine an optimal strategy that will help him in multi-threat encounters. The scope and design in most anti-air warfare studies have been limited to evaluating the effectiveness of detecting sensors and weapon systems in a regular screen formation. The proposed model's (Disposition Mission Model – DMM) characterization, however, is based on how to perform an effective, defensive disposition from a task force. In DMM we focus on usage of a graphical user interface and provide a user-friendly environment for analyzing new tactics in screen formations. The model, with its user interface, allows the user to build and run a convoy simulation, and see the results comparatively on the same interface. The analysis using this model has yielded significant insights towards the defense of a convoy by way of regression methods. It has been seen that positioning the escort ships within the threat sector reduces the damage on the HVU and also balances the defensive load of each defense ship for the incoming missiles. The model, with its graphical interface and simulation components, provides an initial approach for future analysts, not only in anti-air warfare defense of screen formations, but also in the areas of anti-surface and anti-submarine warfare.

THESIS DISCLAIMER

The reader is cautioned that the computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

TABLE OF CONTENTS

| | | |
|-------------|--|-----------|
| I. | INTRODUCTION | 1 |
| A. | BACKGROUND AND PURPOSE | 3 |
| 1. | Graphical User Interface (GUI)..... | 5 |
| 2. | Simulation | 5 |
| B. | OBJECTIVES | 6 |
| C. | RESEARCH QUESTIONS..... | 7 |
| 1. | Initial Research Questions..... | 7 |
| 2. | Secondary Research Questions | 8 |
| D. | METHODOLOGY | 9 |
| 1. | Modeling Methodology..... | 9 |
| 2. | Analysis Tool | 10 |
| 3. | Analysis Method..... | 11 |
| E. | THESIS OUTLINE | 12 |
| II. | CONVOY OPERATIONS..... | 13 |
| A. | SCREEN FORMATION TACTICS IN WWII..... | 14 |
| B. | MODERN SCREEN FORMATION TACTICS | 15 |
| C. | SCREEN DISPOSITIONS..... | 16 |
| 1. | General Screen Disposition..... | 17 |
| 2. | Two Whiskey (2W) Disposition | 18 |
| D. | SUMMARY | 20 |
| III. | DISPOSITION MISSION MODEL (DMM) | 21 |
| A. | METHODOLOGY..... | 21 |
| 1. | MODKIT and SIMKIT Packages..... | 22 |
| 2. | ASMD Package | 23 |
| 3. | Graphical User Interface | 23 |
| B. | DMM's GUI..... | 24 |
| 1. | Main Scenario Window..... | 26 |
| 2. | Simulation Running Window | 37 |
| C. | DMM's SIMULATION (ASMD MODEL)..... | 38 |
| D. | SUMMARY | 39 |
| IV. | ANALYSIS USING DMM..... | 41 |
| A. | MEASURES OF EFFECTIVENESS..... | 41 |
| B. | INITIAL SCENARIO | 42 |
| 1. | Range and Bearing Factors..... | 43 |
| 2. | Regression Analysis | 45 |
| 3. | Improved Scenario | 47 |
| C. | OTHER SCENARIOS | 49 |
| 1. | Two Screen Ships vs. Two ASM Sites | 49 |
| 2. | Three Screen Ships vs. Two ASM Sites | 52 |

| | | |
|----|--|----|
| D. | DETAILED REGRESSION ANALYSIS..... | 54 |
| 1. | Hypothesis Test | 55 |
| 2. | Interpretation | 57 |
| E. | TACTICS | 59 |
| 1. | Range vs. Bearing..... | 60 |
| 2. | More Than One Ship On Threat Sector..... | 61 |
| F. | SUMMARY | 62 |
| V. | CONCLUSIONS AND RECOMMENDATIONS | 63 |
| A. | CONCLUSIONS..... | 63 |
| B. | RESULTS OF THE ANALYSIS | 64 |
| C. | DEVELOPMENT OF DMM | 64 |
| D. | ADAPTATION OF DMM IN THE TURKISH NAVY | 65 |
| | APPENDIX A. INI FILE INTERACTION IN DMM..... | 67 |
| | APPENDIX B. ASMD MODEL..... | 73 |
| | LIST OF REFERENCES | 79 |
| | INITIAL DISTRIBUTION LIST | 81 |

EXECUTIVE SUMMARY

The quantity, availability, and capability of Anti-Ship Missiles (ASM) pose an ever increasing threat to the safety of naval forces at sea. This ASM threat imposes extra demands on the naval forces operating especially on littoral waters due to the complexity of the conducted operations, geographical constraints, and the limited battlespace in these regions. Reduced reaction time to incoming threats, lethality of enemy missiles, ambiguous threat bearings, and uncertainty in littoral waters create greater vulnerability for naval forces that operate within these regions than for the units in open ocean. Current Anti-Ship Missile Defense systems are deemed adequate for operations in open ocean, but the future is more uncertain for littoral scenarios such as convoy operations. Convoy operations have particular importance in littoral warfare due to their limited maneuver capabilities and the improving capability of land-based ASM's used in these regions. Navigating through the hostile shores and straits with the defensive responsibility of a High Value Unit (HVV) requires an effective defensive formation for the escort ships.

Research and development programs are underway to enhance the capabilities of convoy operations against ASM's both in open and littoral waters by ASM specialists and tacticians. However, further analysis of Missile Defense formations and tactics of screen ships in a convoy against ASM's is clearly necessary in order to see these units safely into the future operations.

Current naval combat models do not provide the tactical commander with sufficient analysis tools to evaluate effective disposition of escort ships. An effective tool should allow the tactical commander to analyze the effectiveness of screen disposition as a whole. Currently, high-resolution models focus only on defense of a single ship and

cannot be easily extended to analyze the problem of screen defense as a whole. Aggregated campaign models do not model either the process of detecting and firing of missiles or defense ship reactions. A new model is clearly necessary to help the decision-maker determine an optimal reaction tactic of positioning the screen ships of a convoy in multi-threat encounters of littoral environments.

The Disposition Mission Model (DMM) was created as a simulation tool to evaluate the effectiveness of different defense dispositions of a task force. In DMM the analyst takes advantage of Graphical User Interface (GUI) to configure the scenarios, run the simulation associated with the scenarios, and evaluate the results.

The simulation part of DMM, the Anti-Ship Missile Defense (ASMD) model, was created by James R. Townsend at the Naval Postgraduate School as his Master's Thesis in Operations Research "Defense of Naval Task Forces from Anti-Ship Missile Attack". It supports realistic object movement simulation with a sophisticated mathematical package. The object movement property of this enhanced simulation model was combined with a user-friendly interface in DMM to design a modern combat model for littoral scenarios. The advantages of the GUI in DMM are:

- Ease of use. Those who might not know the model can easily set a scenario and run the model.
- To provide more quantitative information data necessary for the comparative analysis.
- Capability to simulate a battle space with all entities (ships, sensors, missiles etc.) necessary to form a convoy screen and the hostile elements in a littoral map.

Both exploratory and logit regression analyses utilizing the DMM have revealed significant insights into screen defense of convoy operations. The analysis has shown how to reduce the damage on the HVU and also balance the defensive load of each defense ship for the incoming missiles by positioning the escort ships within the threat sector. Placing the defense ships within the threat sector affects the defense more positively than positioning them on the effective range necessary to cover the HVU.

The results derived from the analysis have also proved the concept that the more screen ships the better defense of the convoy. However, it also showed that for small navies that could not provide many defense ships per HVU, positioning the escort ships within the threat sector would provide an effective defense as well.

The DMM is a powerful tool with its GUI and simulation components in the analysis of screen defense disposition problems. The results obtained from the model are intended to provide more qualitative information than precise quantitative results. The model should be regarded as an initial approach to the future development of related Operations Research topics. The modularity and scalability of the model enables the future analyst to extend his work from the DMM and develop the model into new areas.

I. INTRODUCTION

Naval forces of a nation are the major mobile units capable of operating throughout the world seas. They primarily provide the continuance of several naval roles and missions, such as sea control and maritime supremacy, and naval warfare efforts in both war and peace time. Naval forces are also called on to maintain readiness in order to conduct naval operations in littoral regions around the world. The littoral environment and the potential enemy which may be encountered there impose new demands on the naval forces. The conducted operations, geographical constraints, limited battlespace, reduced reaction time to incoming threats, lethality of enemy missiles, ambiguous threat bearings, and uncertainty equate to greater vulnerability for naval forces that operate within these areas than in the open ocean.

Convoy operations have particular importance in littoral warfare due to their limited maneuver capabilities. Navigating through the hostile shores and straits while escorting a High Value Unit (HVV) requires an effective defense formation for the escort ships.

The Turkish Navy, operating mostly in closed seas like the Aegean Sea and the Black Sea, and the Allied Forces operating in the Adriatic and the Persian Gulf, are indeed working in close proximity to potential adversaries that may possess weapon systems capable of attacking these convoys at sea. The increasing potential hazard presented by Anti-Ship Missiles (ASM's) to the naval forces is currently an overwhelming threat. This threat will not likely change in the foreseeable future since non-NATO countries, such as China and Russia, are making substantial improvements toward the capabilities of their missile systems. Iraq, with its Soviet-built CSSC-3 and Silkworm ASM's, and Iran, with China-built C-81's, are believed to pose a threat to U.S.

warships and the commercial ships in the Persian Gulf.

The U.S. Navy is without question the strongest in the world. No other nation can challenge its ability to maintain sea control or threaten its maritime superiority, at least in the foreseeable future. However, as the U.S. Navy shifts its strategy to include the littoral arena and the support of land operations “from-the-sea”, the primary threats to the force within the littoral region, as in the open ocean, are again becoming land-based ASM threats. Even though the U.S. Navy can obtain detailed information and intelligence over a region via satellites, this ASM threat is still considered a big danger to the safety of its convoy operations all around the world seas. Since this intelligence net does not exist for smaller navies that are not supported by satellites, the increased availability and capability of these weapons in hostile hands necessitates the analysis of defensive tactics.

The Turkish Navy is shifting its operational concept from a defensive role in its surrounding seas (the Mediterranean Sea, Aegean Sea and Black Sea) to being a primary contributor to the Allied Force’s efforts. Recent operations, such as the humanitarian rescue mission in Albania in 1998 performed together with the Standing Naval Forces of Mediterranean ships (STANAVFORMED), active missions in the Adriatic for interrogation of merchant traffic in the region, and convoy operations from/to Italy, are all totally new to the Turkish Navy. Additionally, the crisis between Turkey and Greece over the islands in the Aegean Sea is unfortunately evolving into a situation of armament of Soviet-built ASM’s on the islands. These threats, missions in NATO, and the plan of owning an aircraft carrier in year 2010, reveal the fact that the Turkish Navy must change its weapon systems and tactics necessary to enhance the capabilities and defense of its future naval forces. Even though the new weapon systems for defensive purposes against surface and subsurface missiles have begun to be installed on new ships, the research and

development programs for the new tactics are still underway. Current tactics used in exercises and real operations evolved from experience, and most of the Allied Tactical Publications were optimized for operations in non-littoral scenarios. These tactics still seem usable for Anti-Submarine Warfare (ASW) and Anti-Surface Warfare (ASUW), but not for Anti-Air Warfare (AAW) and related convoy operations due to the improving capability of missiles used in these types of operations.

Tactical complexity is a peacetime problem and must be solved by the tacticians before the war starts. However, the continuing pressure on tacticians to develop new tactics with less cost and more certainty is making this process much more difficult. There have been some debates among many ASM specialists about which methods are superior and less costly in the development of new tactics. One method to estimate and compare the effectiveness of convoy disposition tactics in multiple AAW scenarios is through simulation. The training costs saved, the chance to test ideas cheaply, and the operational insights gained can provide big rewards when applying well-developed simulation methods. It allows flexibility, provides more certainty (even with stochastic processes) and costs less compared to real testing and actual data collection from war efforts. The purpose of this thesis, therefore, is to develop a tool that facilitates an analysis about the new tactics in screen formations that can be adopted for the Turkish Navy. Through the development of simulation components, as well as a comparative analysis, a user-friendly graphic interface that demonstrates a real screen formation in littoral waters will be produced.

A. BACKGROUND AND PURPOSE

For the purpose of this study, AAW is considered in its defensive role in naval warfare. The effective use of sensors and weapon systems and the command and control

process, which are the most important aspects of the AAW, are all defensive supports to the safety of ongoing operations.

AAW as a whole is a multidisciplinary field. Radar, command and control, aerodynamics, infrared, fuzes, warheads, and control systems are combined in the process of shooting at and destroying the surface threats in the defensive role. However, well-formed defensive tactics, integrated with the systems mentioned above, ensure that ships gain a cumulative benefit against the enemy. An effective disposition of the Task Force (TF), for example, will enable the screen Task Force Commander (TFC or known as OTC) to use his/her defensive capabilities in the best way and in the high readiness level against air threats. Thus, forming the appropriate screen for the AAW against ASM's is a very important operational decision for the naval tactical commanders. The appropriate screen will help to regulate the usage and determine the most profitable disposition of ships for the detection and the possible countering of enemy weapon systems.

As stated above, the basic decision problems for the tactical commander are to design an optimal reaction formation, possibly consisting of different types of ships, and to determine an optimal strategy that will help in multi-threat encounters. However, the scope and design in most of the anti-air warfare studies has been limited to evaluating the effectiveness of detecting sensors and weapon systems in a regular screen formation. The proposed Disposition Mission Model (DMM) will be based on how to perform an effective, defensive disposition from a given task force with respect to each ship's weapon and sensor capabilities. This study is designed to help the decision-maker determine the optimal force disposition in air defense of a convoy. In order to assist the decision-maker, the scenario for each tactic is displayed by a user-friendly and interactive

environment, which the decision-maker (Task Force Commander-TFC) can visualize on a littoral map.

1. Graphical User Interface (GUI)

The purpose of the Graphical User Interface (GUI) is actually to decorate the simulation program with a user-friendly environment. The GUI in DMM is designed to help the user in analyzing the effectiveness of the screen formations in an interactive map environment (actual battle space). The GUI is also designed to display the results in a comparative way on the same interface on which each scenario is depicted.

DMM's GUI is also intended to have a very robust and scalable design in order to help the user who might have no idea of defense in convoy operations. The user does not need to know even a computer programming language to execute a scenario and see the simulation results in order to make the analysis. These features also help the future analysts in designing new models, which can extend from the DMM.

Another important issue, which arises in the analysis of the simulation models, is the fact that many different independent scenarios should be built and the simulation associated with these scenarios should be run. Furthermore, the results of these runs must be displayed in an orderly manner for later quantitative analyses. DMM's GUI provides the user with all these essential tools. The usage of the GUI will be the major subject of this thesis.

2. Simulation

There are three ways to study an air defense system scenario. One is to analyze data from actual combat operations; another is to analyze data from controlled system-level tests; and yet another is to analyze data from a simulation [Ref. 1].

The defense establishment of any nation will analyze air defense performance (their own and that of their enemy) for lessons learned from actual combat use. The information from such analyses is valuable, but not for determining whether existing systems can do the job. It might be too late for that purpose after a conflict.

An analysis based on system-level test data has good credibility because the actual software and hardware is used against live targets. However, safety considerations and target performance limitations induce artificialities that can lead to erroneous conclusions. Testing is also expensive and can investigate only a limited number of system configurations and tactical scenarios.

Computer simulation of the air defense scenarios of a task force screen formation/disposition allows greater flexibility – essentially unlimited testing. The simulation results have varying degrees of credibility, depending on how simulation fidelity, with respect to the actual system, is perceived. Overall, simulation has become a more accepted and desirable method of analysis due to the increasing cost of operational trials and complexities of defense systems.

For these reasons, in this thesis, simulation will be used to analyze the defensive performance of various screen formations and tactics.

B. OBJECTIVES

It is recognized that many research and development programs are underway to enhance the tactics of naval forces. In this study, the case of tactics for screen formations is isolated from other cases since screen tactics can be expanded to cover different tactics used in the ASW and the ASUW operations. In the DMM (Disposition Mission Model) we will focus on usage of a graphical user interface and provide a user-friendly

environment for developing new tactics in screen formations against the land-based AAW threats.

It is not the intention of the DMM to propose or build a comprehensive model of maneuver warfare in this study. The environment that will be developed will facilitate the exploration of multiple scenarios and architectures without relying on the veracity of a single run. To manage this goal and to answer the questions about the efficiencies of different screen dispositions in AAW, the thesis has the following objectives:

- To build a flexible, modular and expandable screen defense simulation using MODKIT, SIMKIT and ASMD model (They will be covered in the third chapter).
- To build a GUI that displays an actual littoral battlefield in which an HVU escorted by screen ships can navigate, while providing the user with an easily modifiable scenario.
- To analyze the result of each scenario by referring only to the GUI in which the AAW simulation is run.
- To give a start and provide a base for the Turkish Navy in making war games for convoy operations and other future missions.
- To provide a base for follow-on Operations Research (OR) thesis researchers.

C. RESEARCH QUESTIONS

1. Initial Research Questions

The air defense system simulation can be a burden on the analyst if the designed process is not properly prepared. It is vital that the model performs as intended over the

range of operational conditions to which it may be subjected by the decision-maker. The model must also be suitable for different kinds of tactics and performances. The behavior of the system can be determined by some particular details in the model: scenarios, resolution of the model and the components that form the model. All these issues must be reasonably accurate. In order to maintain this accuracy, the research questions below will be explored throughout this study:

- What should be the discrete event simulation and GUI components required in constructing a TF defense model for analyzing efficiency of different screens formed around a High Value Unit (HVV)?
- What should the model resolution be?
- What are the important battle scenarios for the Turkish Navy to analyze effectiveness of different screen dispositions for convoy operations and how should the model be constructed to run these scenarios?
- Which tactics can be derived from this analysis and will prove to be sufficient in the future?

2. Secondary Research Questions

The objective in air defense (of convoy operations) analysis is to predict the system effectiveness. There are several system effectiveness measures that can be studied. By stating this effectiveness measure, the objectives of the model becomes clearer. In this scope, the secondary research questions will be searched and explored in the later chapters of this study:

- Which variable inputs should be fixed for analysis purposes?
- What are the appropriate Measures of Effectiveness?

- What is the appropriate method for sampling strategy and analysis to demonstrate the utility of this model?

Since DMM will be a tool used to study the effectiveness of a task force screen against the ASM's and to help the decision-maker achieve specific objectives in a tactical environment by determining the appropriate screen formation, the scope of the thesis will also include:

- A collective usage of the ASMD model and Java™ programming language to create a user-friendly GUI simulation model for a variety of combat situations of a screen in convoy operations.
- An analysis of the effectiveness of new tactics associated with screen ships and their dispositions on a formation for naval area ASM defense by using the DMM.

D. METHODOLOGY

1. Modeling Methodology

a. Discrete Event Simulation

This thesis will incorporate a component-based discrete event simulation approach using the Java™ programming language. Discrete event simulation concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time. These points in time are the ones at which an event occurs, where an event is defined as an instantaneous occurrence that may change the state of the system [Ref. 2]. In the DMM, positions of each entity including sensors, weapons and movers are recorded at each next-event time advance in which the state of the system is updated, and future event times are determined.

b. Components and Modularity

Discrete event simulation models all share a number of components in a logical organization. The ASMD model uses entities at the composite unit level. A composite unit is a group of components that operate together. Each composite unit is created from several smaller components that seek to model the precise behaviors of the composite unit. On the battlefield most entities, such as ships and ASM/SAM's (Surface to Air Missile), can be seen in a component-based behavior with their controllers, movement, sensing and interaction elements. The DMM, using only the behaviors of each component in the ASMD model, will share this component-based simulation modeling.

The modularity of the system provides easy and fast adjustments, additions and removals to the model. The model is scalable to support analysis of different force sizes and mixes. The model therefore provides the necessary properties to analyze one frigate screen task force or a destroyer group in a screen formation with little effort. All those adjustments will be easily handled by the DMM with its GUI that can display and run multiple scenarios.

2. Analysis Tool

The DMM will be utilized in order to decide what escort ship spacing and orientation patterns are to be used in screen formation, and where each screen ship must be positioned in the formation to minimize the threat posed by the ASM sites. The graphical user interface will enable easy evaluation and manipulation of scenarios in order to analyze different formations.

3. Analysis Method

a. *Input Analysis (Exploratory Analysis vs. Traditional Analysis)*

Since models are only approximations of actual systems, their reliability depends in part on the quality of the input data. In this study it has been very difficult to obtain accurate input data, such as the exact range of detecting sensors and weapon systems etc., because of their high-level security clearance requirements. Therefore, Exploratory Modeling [Ref. 3] was employed. The model was run many times with many different input levels, thus producing a large number of possible combinations. For exploratory modeling, “a large space in the domain of interest (and all the solutions in it) will be examined, then a solution will be selected” [Ref. 3]. In traditional analyses, the solution is found and the area around it is examined. Exploratory analysis not only provides the necessary decision flexibility, but it also reduces the risks associated with imperfect input data; an important consideration of this thesis.

b. *Output Analysis (Logistic Regression)*

Logistic Regression analysis was used as statistical method for output analysis. Regression summarizes and models complex data in a compact way. Regression models are easy to describe, study and compare. The models can also be used to make predictions. Regression encompasses a broad range of methods, from elementary to advanced with respect to the complexity and the number of predicted variables. The DMM’s output deals with percentage of the HVU’s casualty: 50% means half of the missiles fired against the HVU are on target while the rest are destroyed by defensive means (escort group). The criteria of whether the HVU is damaged (or not damaged) will be based on the percentage of ASM hits on the HVU.

In regression, categorical variables, such as percentages, probabilities and two or more choices (yes-no, for and against, etc.), can be predicted by way of the logit (also called logistic) regression method. Like elementary regression, logit regression provides a flexible, general-purpose modeling strategy with straightforward interpretation. The use of logit regression in this analysis will reduce several problems caused by unrealistic predictions, which imply that some unrealistic parameters were estimated. The logit regression, together with its usage in this proposed thesis, will be covered in detail in the fourth chapter.

E. THESIS OUTLINE

This thesis consists of five chapters. This first chapter has introduced the problem statement and discussed many of the pertinent subjects necessary to solve this problem in a unified introductory level.

The second chapter covers the history of convoy operations and screen formation tactics used in convoy operations. There is little published information about convoy operations and its tactics, and this chapter provides some extra background.

Before going directly into the simulation, it is helpful to overview the discrete event simulation and its components. The third chapter describes the DMM and its components together with Java™ Swing components necessary for the GUI.

The primary subject matter of the fourth chapter is the Measure of Effectiveness and the comparative analysis of the results using regression analysis methods. The results, derived from the regression analysis methods, are evaluated in this chapter.

The fifth chapter contains the final conclusions and recommendations concerning the results and possible future research areas.

II. CONVOY OPERATIONS

In the previous chapter, we have stated the purpose of the new model and discussed some of the pertinent subjects necessary to build this kind of model. But before getting directly into the models' functionality, some standard definitions and background information must be covered initially. This introductory information will provide insight into the model's design and also provide a basis for the application of the model.

Simply stated, a convoy is a number of merchant ships or naval auxiliaries, (or both,) usually escorted by warships and/or aircraft, or a single merchant ship or naval auxiliary under surface escort assembled and organized for the purpose of safe passage together. If this convoy's voyage lies, in general, on the continental shelf in littoral waters then it is called a coastal convoy. Escorting refers to the act of ships or aircraft that accompany and defend valued units from enemy weapons. Escorting is one kind of counterforce performed for the goal of the operation. Thus an AAW screen, for instance, is primarily an escort counterforce to protect other units from ASM or aircraft attacks [Ref. 4].

Originally, the first convoys of merchant ships were formed as a protection against pirates. The tactics for the convoy escorts against pirates were simply based on the idea of positioning the escort ships between the merchant ship (which is the HVU) and the pirate ships.

The first great naval engagement of the French Revolutionary wars was fought between the French and the British in the Atlantic Ocean about 430 miles west of the Breton island of Ouessant. The battle arose out of an attempt by the British Navy, under Earl Howe, to intercept a grain convoy from the United States to France. The practice at the time was to position the escort battle ships all around the grain convoy.

Since Early Howe was attacking with a huge crowd of ships from every sector, the practice of forming the screen ships around the grain carrier ships was deemed to be appropriate.

A. SCREEN FORMATION TACTICS IN WORLD WAR II

During the Battle of the Atlantic in the early years of World War II, the German U-boats were sinking allied merchant ships at such an alarming rate that new tactics had to be developed immediately. In reviewing data arising from OR practices during and after the WWII, several countermeasures against anti-convoy encounters were invented and some were successfully employed. Equipping merchant vessels with antiaircraft guns and anti-torpedo nets helped greatly, considering the equipment performance. But the installation of nets was expensive and also slowed down the speed of the convoy and antiaircraft guns were needed in many other places besides ships [Ref. 5].

The first American carriers, arriving in the Atlantic in early 1943, soon found that the practice of operating the carrier within the convoy screen was inefficient. Launching and landing aircraft requires the carrier to turn into the wind, which of course was not always the direction in which the convoy was sailing. Frequent maneuvering within the convoy, particularly at night during flight operations, disrupted convoys operation and always increased the risk of collision. The U.S. Navy adopted a mode of operation where the carrier and its escorts sailed outside the convoy but remained close enough to enable proper air cover.

The tactics, as mentioned above, have always changed to increase the safety of convoy operations. For example, the most important trend in the midst of World War II was an amalgamation of the types of surface ships supporting convoys. In 1945, cruisers

were armored big-gun ships that were capable of operating independently for protracted periods. Destroyers were part of the screen protecting the main fleet, and frigates were slower ships designed for the escort of merchant traffic.

B. MODERN SCREEN FORMATION TACTICS

Evaluating the enemy's rapidly changing countermeasures during the World War II shows that most of them consisted of the renewal of the ship classes or installation of new equipment onboard convoy ships to reduce casualties caused by the enemy. But now, since most of nations capabilities for war are known in terms of platform and weapon lethality, the need of developing and implementing counter-tactics, doctrines, and effective training program to gain proficiency in naval operations is more important. The danger caused by submarines in World War II has been replaced with the danger of air attacks such as missiles and aircraft. Captain Wayne P. Hughes (USN, Retired) states that "...universally recognized are these two facts: technology advances keep weapons in a state of change, and tactics must mate with the capabilities of contemporary weapons" [Ref. 6].

In the early to mid 1950's the Soviet Union developed a missile boat concept that envisioned offensive, defensive, and special operations attacks with numerous patrol craft within 20 to 30 miles of shore [Ref. 7]. In the late 1950's, they had produced Komar and Osa fast patrol boats armed with Styx missiles (25-30 mi. range). By delivering these boats along with the Styx missile to the Egyptian Navy in the early 1960's, they totally changed the weapon balance of naval power between Israel and Egypt. The Israelis understood that the merchant traffic in the region would face drastic danger. Their fleet, then consisting mostly of ex-British World War II vintage Z class destroyers, was no match against faster patrol craft equipped with accurate long-range ASM's. They soon

realized that their navy required immediate force and equipment changes and, equally important, such an undertaking would require revision of concepts of operations, doctrines, tactics and training. First they developed the Gabriel ASM with 12-mile range. The positioning of screen ships (Z class destroyers) to avoid or destroy the enemy before being destroyed by them became paramount. The Gabriel missile was out-ranged ten to fifteen miles by the Styx missile. In other words, an Israeli ship would have to approach the enemy more than ten miles inside the Styx missile range before they could fire missiles. With this in mind, the concept called for a new tactic of defending the convoys from outside the screen; maybe, miles away from where the convoys are. Scouting procedures, EMCON conditions, electronic warfare, hardkill and softkill defense factors, coordinated ASM attacks, as well as gunnery procedures, were developed and extensively tested both at sea and inport with the use of state-of-the art tactical trainers in Haifa, Israel. The Battle of Latakia on October 6, 1973, in coastal waters off the coast of Syria was the first in which these Israeli concepts were put into action. There were no casualties to the Israeli force while six Syrian boats were sunk during the battle. The tactical concept, together with written and well-performed doctrines, helped the Israeli forces against their strong enemy.

C. SCREEN DISPOSITIONS

Tactics are the methods by which forces are employed and handled in battle and include: acts of deployment, maneuver, and application of force. But tactics alone can not win battles. They must be combined with training and experience learned from past efforts and must be performed in appropriate scenarios.

Considering the success managed by the Israeli Navy, there are many examples of

important improvements and usage of tactics. Among those improvements, two main screen disposition tactics for convoy operations are still in use: the general screen disposition and the two-whiskey (2W) disposition. Even though only the general screen disposition will be analyzed in this thesis, the 2W disposition is considered worthy of mentioning for completeness. In order to evaluate how well the commander is prepared tactically to conduct the AAW screen dispositions, these two main disposition tactics which are still being used by the Allied Forces are summarized below:

1. General Screen Disposition

The general screen disposition is performed for not only the AAW missions, but also for the ASW and ASUW. It is appropriate for many multi-threat encounters. The HVU (merchant vessel, aircraft carrier, etc., to be protected) becomes the guide of the convoy. The OTC assigns each escort a designated sector according to their sensor and weapons range. All screen ships take sectors with respect to the guide in range and true bearing as assigned. The convoy takes the course in which the guide of the convoy must sail. The OTC can change the convoy speed and course by changing the guide's course and speed. All escort ships have to adjust their speed and course to stay within the assigned sector. Wherever the guide sails, these ranges and bearings must be maintained. Thus, all escort ships are free in their maneuvers as long as they stay within their sector.

Figure 1 is an illustrative example of a general screen disposition in which there is no space between sectors for a submarine to pass through or for an ASM to reach the guide before it should be detected by any of the escort ships. The sectors are:

- Escort ship1: 340°-030° and 8-20 NM.
- Escort ship2: 030°-165° and 15-20 NM.

- Escort ship3: 165°-265° and 15-20 NM.
- Escort ship4: 265°-340° and 15-20 NM.

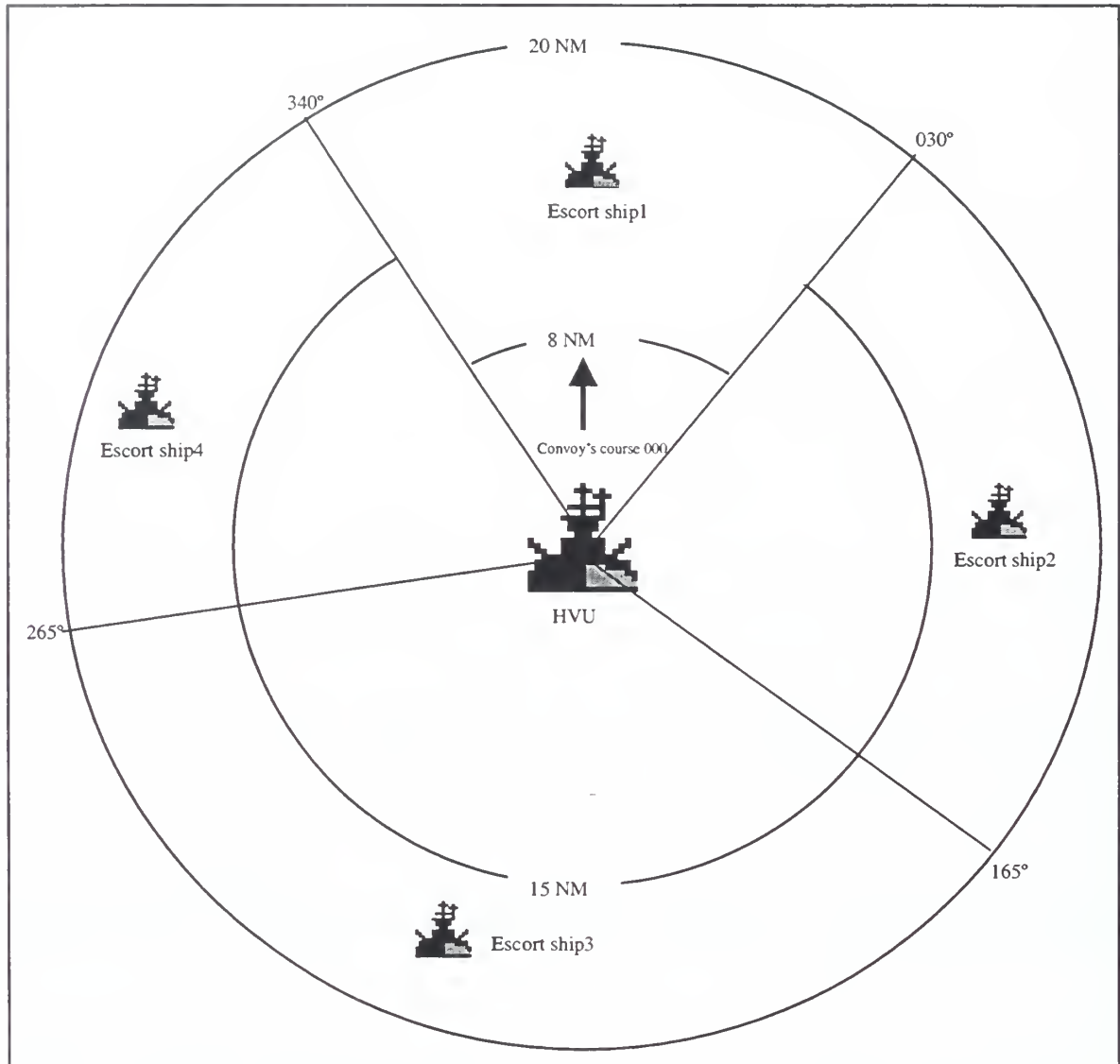


Figure 1. General Screen Disposition, showing the escort's sectors.

2. Two Whiskey (2W) Disposition

Unlike the general screen disposition, the 2W disposition is designed to form an umbrella-like defensive shield only against AAW threats. It is more effective than the general screen disposition if performed with more than five screen ships. It allows a

layered sector defense by assigning more than one ship in the same threat axis. Figure 2 is a standard template used for 2W disposition.

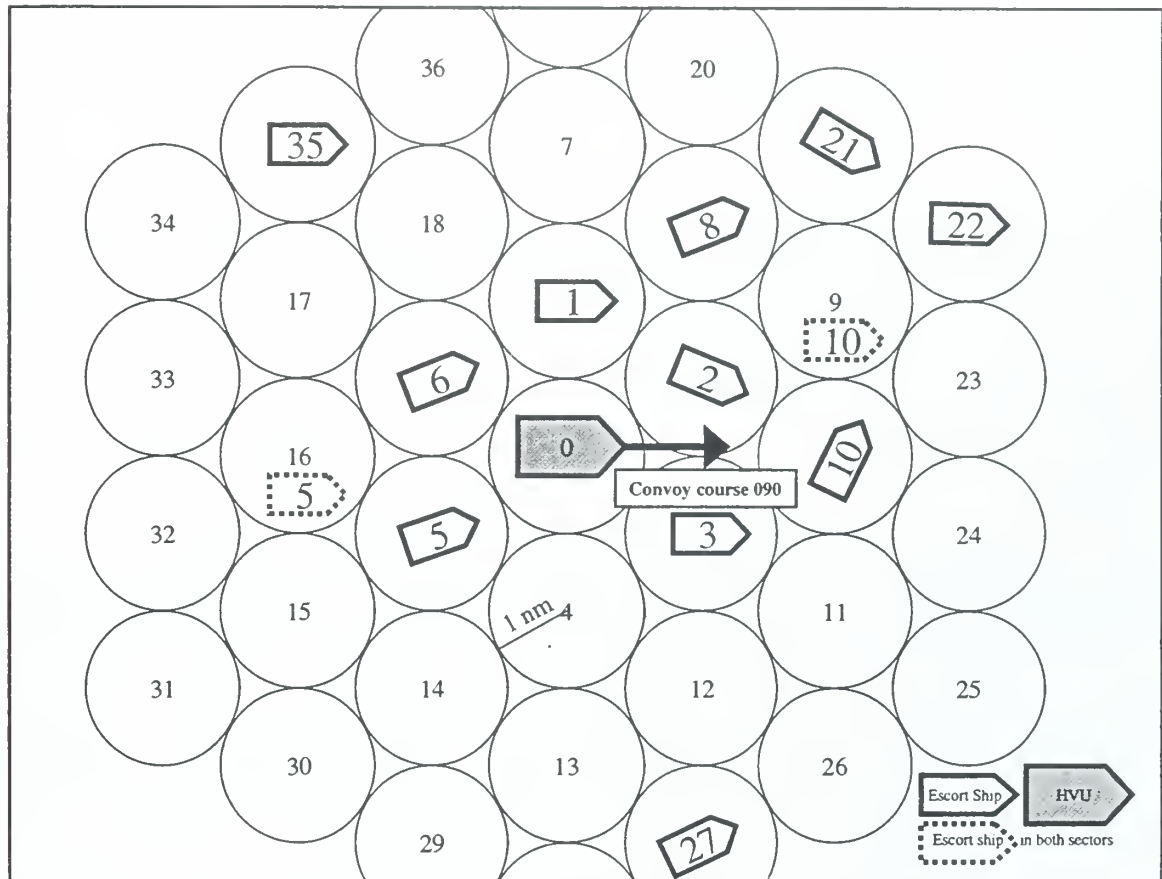


Figure 2. Two Whiskey Disposition, providing defensive shield on the northeast sectors.

As seen in Figure 2, the convoy's course is general east, but escort ships are free to maneuver as long as they maintain their sectors. They could actually maneuver in order to assign their weapons to designated air targets effectively. Additionally, the escort ships can cover more than one sector as illustrated in Figure 2.

Due to its multi-threat defensive capability (against air, surface and subsurface), and since it requires fewer escort ships than 2W disposition, only the general screen disposition will be used in the DMM's GUI to build the scenarios. The advantages of using the general screen disposition are:

- It can be formed effectively even with a few screen units (Some might not have many ships ready and on hand to escort a convoy).
- Many new tactics can easily be derived from general screen disposition such as hiding the HVU inside the screen and greyhound tactics for fast patrol boats.

The general disposition is also preferred by the Turkish Navy due to the geographical constraints of the battle space (the Adriatic, the Aegean Sea, etc.) and limited number of escort ships per HVU.

D. SUMMARY

In essence, tactics are the key elements of command and control. On the day of the battle, a naval force will fight as well or as poorly as they are prepared tactically. Naval forces must possess the capability to conduct any operation in order to control the naval arena. This can be managed by the help of tactics developed to overcome the enemy's capabilities.

This chapter covered the development of screen disposition tactics necessary for convoy operations. Of the two introduced dispositions, the general screen disposition will remain the focus throughout this thesis due to the reasons stated.

The screen dispositions exist only with their entities like ships, their weapons and sensors. These entities will be introduced in the next chapter with the necessary GUI elements used in DMM. The reasons for creating DMM, and briefly, how it works will be the main subject in the next chapter.

III. DISPOSITION MISSION MODEL (DMM)

In this section we will examine the operation of the DMM. The model consists of two distinct but collaborating parts: the graphical user interface and the simulation component, both written in Java™ programming language. We will focus on the structures of these two components, each of which has completely different properties. GUI components will be discussed in detail, while the simulation components (ASMD model) will only be briefly summarized. Component summaries will begin with a listing of the associated properties and will be illustrated using related figures.

A. METHODOLOGY

An operations analyst knows that effective analysis requires the models to have flexibility, modularity and scalability. Another important feature is that the model should be independent of the platform. The Java™ programming language is a very good solution to all of these problems. It is object-oriented, dynamic, and enables modular design. Because of its platform independence feature, Java™ is becoming the language of the Internet. Java™ also offers vastly greater support over its predecessors for developing graphical user interfaces and graphical applets/applications. It provides every basic set of components to implement any applet/application interfaces that are used in today's software products.

Using this language for the discrete event simulation modeling will give the operations analyst more flexibility and, most importantly, more time to devote toward analysis. An AAW analyst, for example, should easily adapt a newly developed sensor in the simulation model and conduct the analysis for a single ship or for a task group without spending much time on model adjustments. The purpose of developing Operations Research (OR) types of combat components is to provide a library of reusable

software to speed development of OR applications and make them more reliable. The following paragraphs will discuss three steps taken to develop this analysis into an OR combat model.

1. MODKIT and SIMKIT Packages

In earlier theses at NPS, very useful combat modeling Java™ packages were introduced such as MODKIT and SIMKIT. MODKIT (developed by Major Arent Arntzen, Norwegian Air Force) is a collection of classes for OR modeling based on the “loosely coupled object architecture” [Ref. 8]. The loosely coupled object architecture has the goal of designing and developing architecture for dynamic map-based military planning applications using new platform-independent software technology. The loosely coupled component architecture operates on a computer network and accesses data, algorithms and other information over the network. Additionally, it supports Monte Carlo simulations as well as visual presentation of the solutions. The architecture further supports collaboration among planners on the computer network and allows the components to be designed and constructed independently of each other and to be easily added to the system. SIMKIT (developed by Professor Arnold Buss and Kirk Stork, a graduate of NPS) is a Java™ library for constructing discrete event simulations that takes an entity-based approach to modeling and simulation [Ref. 9]. SIMKIT provides modelers the ability to construct scenarios using the various platforms and systems and to construct their models by assembling the appropriate component models from various sources. Each component model would be ideally retrieved from the source at run time ensuring the most up-to-date version is in use.

2. ASMD Package

SIMKIT and MODKIT were used in several Naval Postgraduate School Master Theses in order to provide analysis for naval combat models. Among those models, the Anti-Ship Missile Defense (ASMD) model, created by James R. Townsend, has relevant importance [Ref. 10]. It allows for more realistic object movement simulation owed to a substantial supporting mathematical package. Instead of focusing solely on the defense of a single ship in AAW, the simulation can be extended to analyze the problem of screen defense as a whole through the use of this package. Since the DMM was inspired by the ASMD model, we will cover ASMD and outline the necessities for DMM.

3. Graphical User Interface

Data becomes more informative and allows the user to be more perceptive when presented visually. Graphical User Interface (GUI) is the tool to give this visual support to the user. From the desktop level to client/server development applications, software has turned toward GUI's in the last two decades. Successful design for GUI's requires a multi-disciplinary effort. Graphic design, human factors and software engineering skills all play a vital role in this effort.

The most important component of a GUI application is the interface. If the application is too difficult to navigate or understand, the users will reject it, support and training costs will greatly increase, programmers will get discouraged and maintenance will be increasingly difficult. Thus, GUI applications must be designed to effectively meet today's demanding software needs. Java™, with its "Java Foundation Classes" (JFC), has become one of the most effective programming languages with regard to its vast amount of graphic tools. JFC includes the next generation GUI toolkit that Sun Microsystems is developing to enable enterprise development (large scale applications).

In April of 1997, JavaSoft announced JFC which supercedes (and includes) the initial release of Abstract Window Toolkit (AWT). A major part of the JFC is a new set of user interface components that is much more flexible, complete and portable. These new components are called “Swing.” With Swing, interfaces with tree components, tables, tabbed dialogs, tooltips, and many other features that computer users have grown accustomed to can be easily designed. In reality, Swing is more than this. In addition to the new component, Swing makes two major improvements on the AWT. First, it relies less on the runtime platform’s native components, improving performance. Second, because Swing is in complete control of the components, it is in control of the way components look on the screen and allows the user greater control of how the applications look. This feature is called Pluggable Look-and-Feel (PLAF). All these features help the programmer in displaying the components on screen efficiently, registering for events and getting information from them [Ref. 11].

The DMM’s interface was written using Swing components. Main windows (JFrame), tree component (JTree), tabbed frames (JTabbedPane), menus (JMenu, JMenuItem), etc., are all examples of Swing components used to build the DMM. All these components will be covered in detail in the following section of this chapter.

B. DMM’s GUI

DMM’s GUI consists primarily of two frames: the main scenario window and the simulation running window. These two window frames distinguish the scenario from the simulation part. The scenario, after being built, is run in the simulation window

on which the simulation results are displayed after the run is complete. Figures 3 and 4 show the main scenario and simulation running windows respectively (realistically, in a static medium such as paper, it is hard to show that the ships are moving and missiles are being fired by the ASM's sites within the simulation running window).

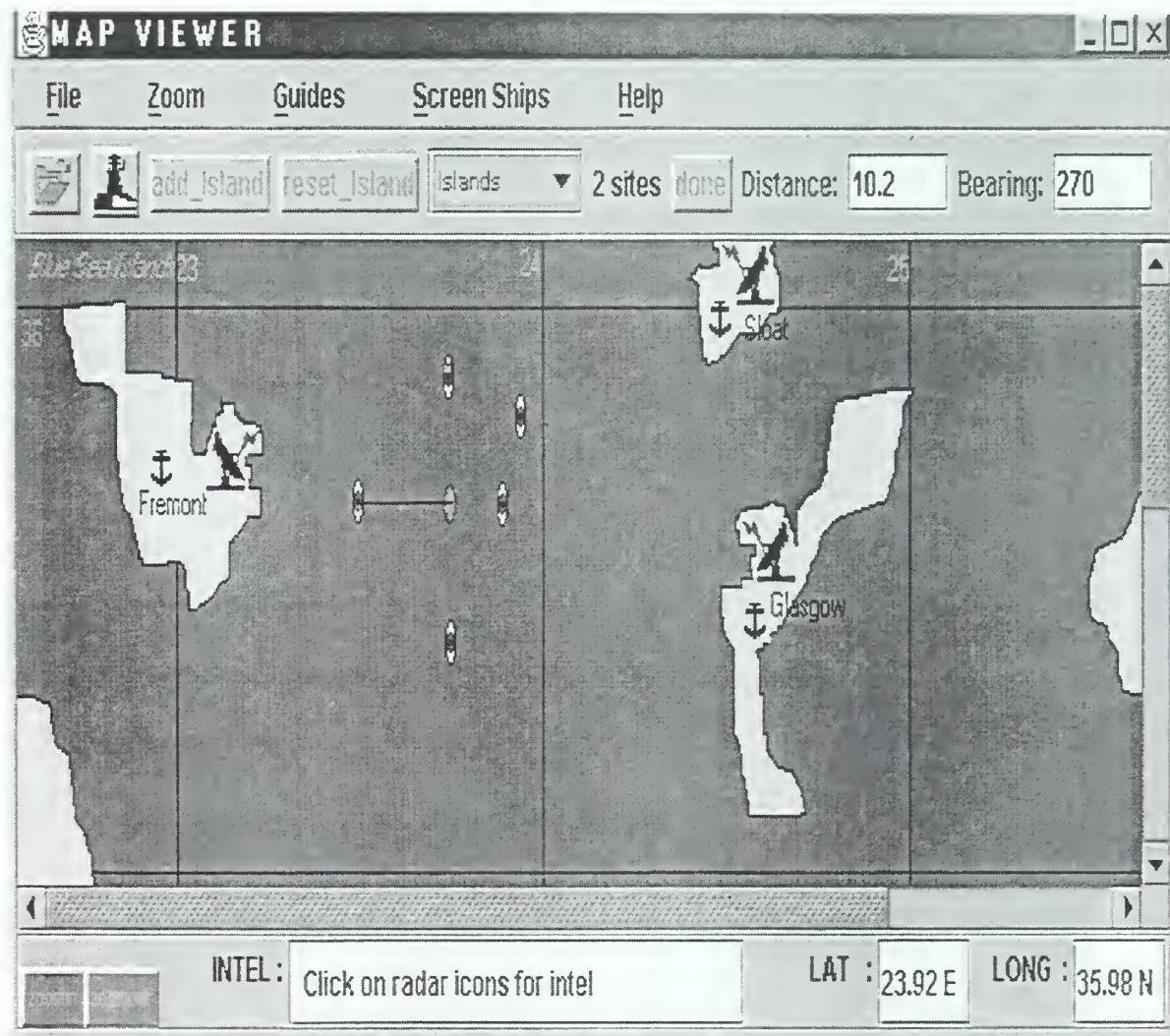


Figure 3. Main Scenario Window, displaying a 6-ship-convoy in a littoral area. The distance between HVU and one of the escorts is 10.2 NM and the true bearing from the HVU is 270°. The cursor is last moved to 35.98N and 23.92E.

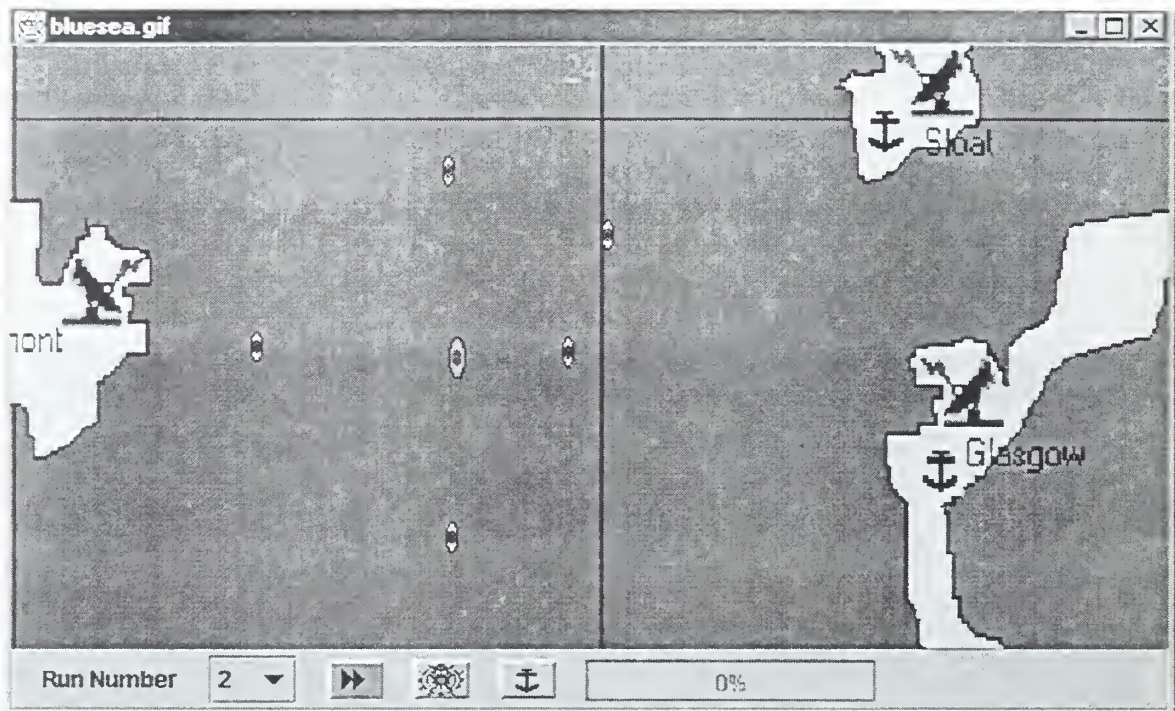


Figure 4. Simulation Running Window, displaying the convoy after run button is clicked. The simulation will run twice. The wheel and anchor buttons are used for information about the scenario and the results after the last run ends.

1. Main Scenario Window

This window is used to build the scenario on a map. The features of this window are:

- Zooming in and out of the map (Zoomin/zoomout buttons and menu items)
- Displaying latitude and longitude (Mouse movements)
- Displaying distance and bearing information (Mouse dragging)
- New ships with new features can be added or deleted (Ship Explorer)
- Help (Help menu/window)

a. Zooming in/out

Both AWT and Swing provide extensive support for image filtering. The image filtering is a tool for scaling an image to any size. The idea is based on scaling and then spreading every bit of the image to the desired scale. Java image producers produce the bits of the image and pass them along to an image consumer whose duty is to put the bits of the image into an array. Once production of the image starts, producers invoke the consumer's methods to deliver the array of bytes of produced image in one shot and without failure. Figure 5 illustrates the usage of image filtering.

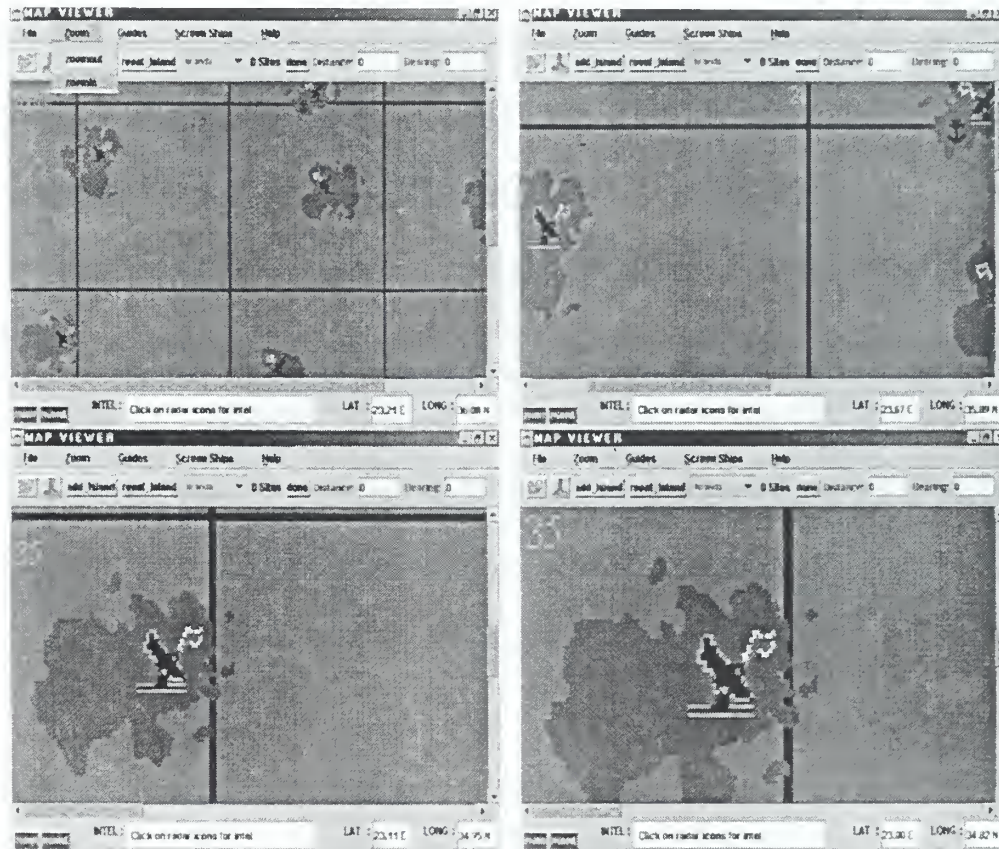


Figure 5. Zooming in three times (from left to right), the first is the original map, the others are zoomed maps by twice, three and four times respectively. Zooming out will reverse the image to its last scale. Zoom menu (as seen in upper-left picture) or zoomin/zoomout buttons (in the lower-left panel of each frame) can be used for this purpose.

There are two main classes in AWT to reproduce and scale an image: CropImageFilter and ReplicateScaleFilter. CropImageFilter crops a specific rectangle of an image while ReplicateScaleFilter scales images by using a single algorithm that replicates rows and/or columns of image data for scaling up, and removing rows and/or columns of data for scaling down. In the DMM, only ReplicateScaleFilter is used for the reasons explained below. Since the map is viewed inside a scroll pane (JScrollPane), cropping the required piece of the image and then enlarging that piece is not a necessity. By scrolling the image, one can view any part of the enlarged map.

There is another alternative in scaling the image: AreaAveragingScaleFilter. The AreaAveragingScaleFilter, which is an extension of the ReplicateScaleFilter, uses a more sophisticated algorithm. This algorithm produces images of a better quality than images scaled by using ReplicateScaleFilter [Ref.12]. However, the better image quality comes at a price. AreaAveragingScaleFilter is slower than ReplicateScaleFilter and causes an insufficient memory problem that might terminate the program. Zooming in ten times to an image with ReplicateScaleFilter causes no difficulty in memory capacity while three times with AreaAveragingScaleFilter does (using Intel Pentium 200MHz PC with 32 MB RAM). Thus, ReplicateScaleFilter method is considered to be a good tool to be used in DMM. Here is the method to scale an image in the DMM:

```
public Image scaleImage ( int zoomingFactor ) {  
    int width = zoomingFactor * originalImage.getWidth (this);  
    int height = zoomingFactor * originalImage.getHeight (this);  
    ReplicateScaleFilter filter = new ReplicateScaleFilter (width, height);  
    FilteredImageSource fis = new FilteredImageSource (originalImage.getSource (), filter);  
    return createImage(fis);  
}
```

In the aforementioned method (scaleImage (int zoomingFactor)), the original image is enlarged the “zoomingFactor” times and image producer produces the new image. This method is fast and produces a quality image, which is enough for the DMM zooming purpose.

b. Displaying Latitude/Longitude and Distance/Bearing

The DMM provides excellent information regarding location and distance/bearing from any point on the map. Every mouse movement within the map is displayed as latitude and longitude information in the very lower-right text areas. If the mouse is dragged from one location to another, the distance and bearing from that location to the last dragged point can also be shown in the upper-right text areas while a line between these two points is drawn on the map. This feature helps the user position the screen ships with respect to the ASM sites. After the guide is in its position, measuring the bearing and range to the ASM sites will be very important in the positioning of the screen ships. With AWT’s MouseMotionListener, this feature can be easily implemented. “Mouse moved” and “mouse dragged” events are referred to as “mouse motion” events. These motion events are presented by the MouseEvent class. The MouseEvent class provides methods that can be used to determine the position of the mouse at the time of the event (getPoint(), getX(), getY()). Here is the code used in the DMM:

```
public void mouseDragged ( MouseEvent e ) {  
  
    // while dragging the cursor takes plus sign shape (+)  
    setCursor ( Cursor.getPredefinedCursor ( Cursor.CROSSHAIR_CURSOR ) );  
    drawDistance ( e.getX(), e.getY() );//draws the line  
    findDistance ( first, e.getPoint() ); //first is the point where the dragging starts  
    findBearing ( first, e.getPoint() );  
    setToString ( e.getX(), e.getY() ); //writes down the position into text fields even  
    // while the mouse is dragged  
  
}
```

```

public void mouseMoved ( MouseEvent e )

    // while mouse moved the cursor takes hand shape
    setCursor ( Cursor.getPredefinedCursor ( Cursor.HAND_CURSOR ) );
    setToString ( e.getX(), e.getY() ); //writes down the position into text fields
}

```

The other events (except mouse moved and dragged) such as mouse clicked, entered, exited, pressed, released are simply mouse events (not mouse motion events), and are also represented by MouseEvent class. The code below indicates how mouse event method (mouse pressed) is used in the DMM. The information pertaining to which mouse button is pressed is provided by SwingUtilities class static methods.

- isRightMouseButton(MouseEvent e)
- isLeftMouseButton(MouseEvent e)

```

public void mousePressed ( MouseEvent e ) {

    //every time mouse pressed the cursor takes the plus sign shape (+)
    setCursor ( Cursor.getPredefinedCursor ( Cursor.CROSSHAIR_CURSOR ) );
    first = e.getPoint(); // first point starting to drag
    /* right mouse button click erases the line drawn, and resets the text fields for distance
    and bearing to zero */
    if ( SwingUtilities.isRightMouseButton ( e ) ) {
        clearDrawLine ( );
        distanceField.setText ( "0" );
        bearingField.setText ( "0" );
    }
}

```

Figures 3 and 5 illustrate how main scenario window displays the distance and bearing information as well as the location.

c. *Ship Explorer*

Swing trees display hierarchical data by using a well-known paradigm of folders and leaf items. The most widely used tree component is undoubtedly Windows Explorer, which contains a tree component for navigating directories. Ship Explorer is based on the same idea of displaying the convoy ships and their features in a hierarchical manner. Ship Explorer takes its initial structure from an INI file (ships.ini). INI files

consist of blocks, which are labels surrounded by square brackets ([]), and key/value pairs, which are separated by equals (=). The INIFileProperties class written by Professor Arnold Buss at the Naval Postgraduate School, Monterey, California provides a mechanism to read the blocks and key/value pairs and loads them into HashTables. The Ship Explorer takes the blocks from the INI file and adds them as a node to the tree. The properties of each ship are added to the tree as leaves. Figures 6 and 7 illustrate the related part of the INI file and Ship Explorer.

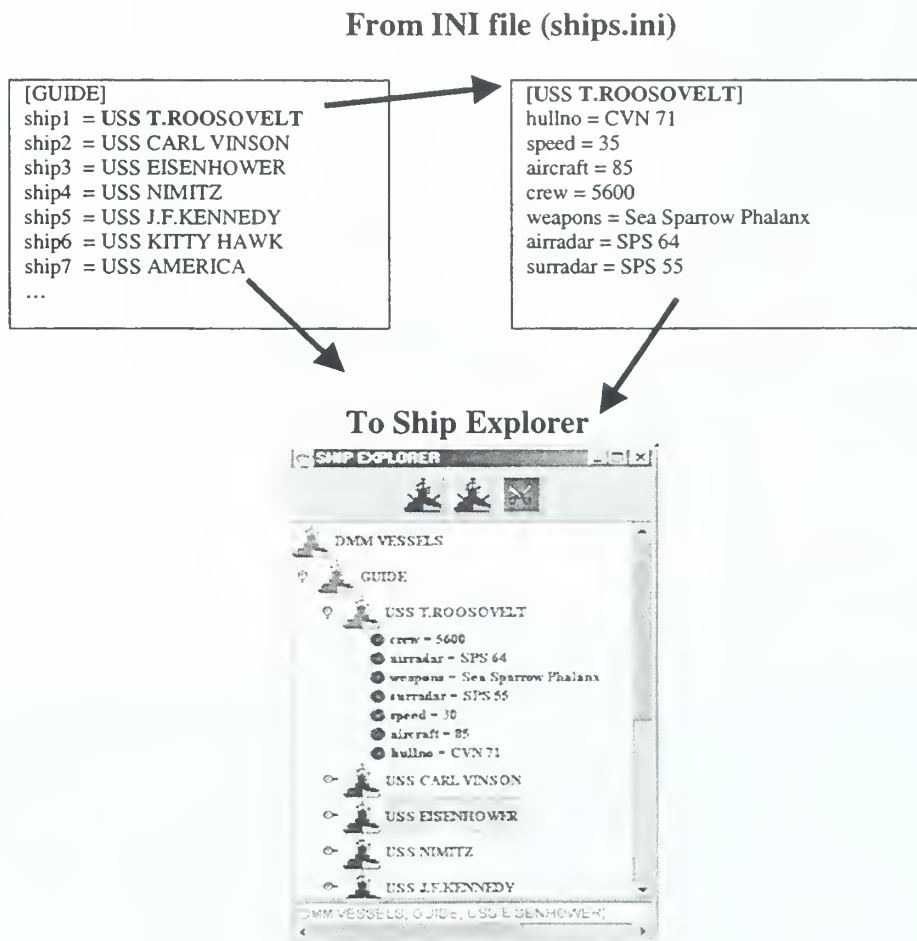


Figure 6. INI file and Ship Explorer, child nodes of guide node are guide ships. The leaves are the properties related with each ship. The cut button is enabled as long as a ship (guide or screen ship) is selected. The other two buttons on the upper panel are used to add a guide or screen ship.

From INI file (ships.ini)

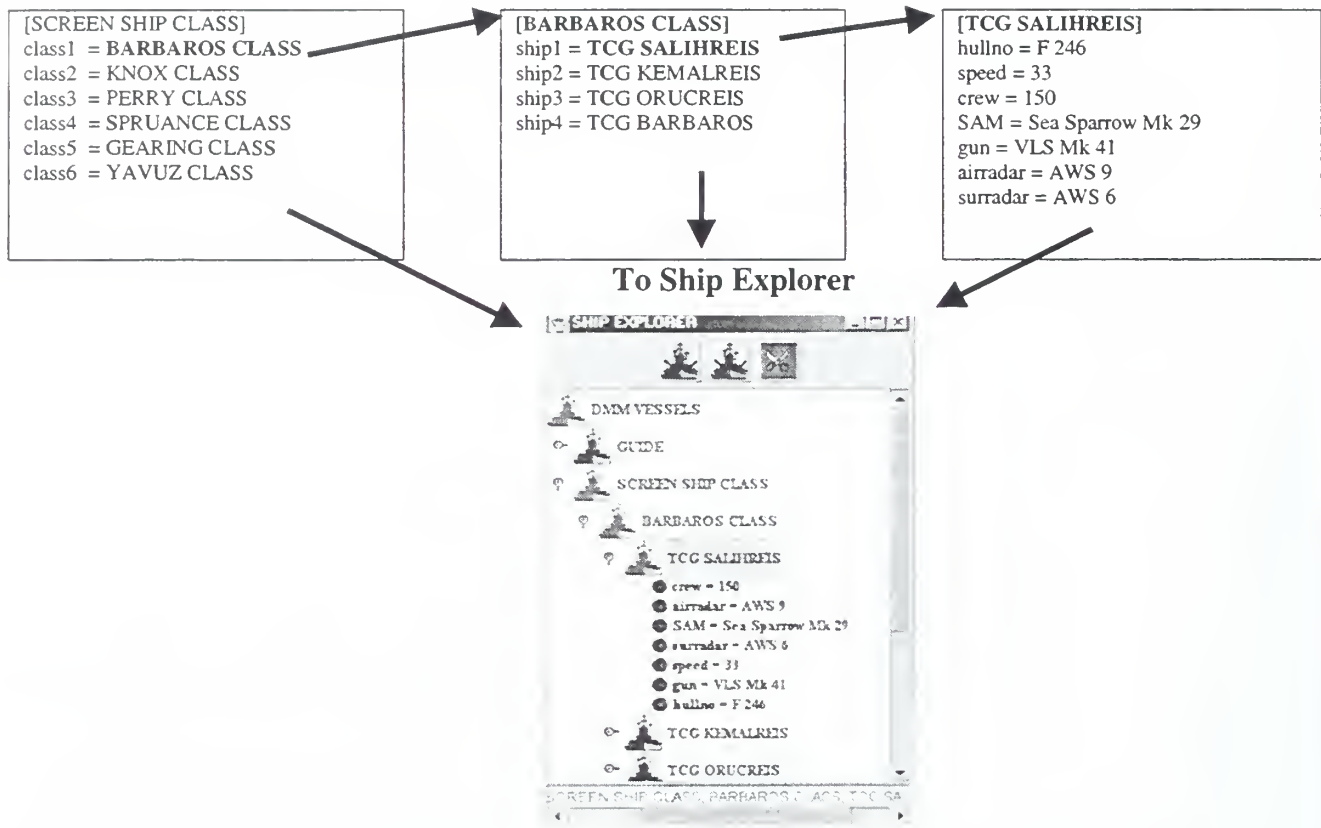


Figure 7. INI File and Ship Explorer, child nodes of screen ship class are ship classes whose child nodes are related ships. Leaves are the properties of each ship.

The guide menu and screen ships menu in the main scenario window takes its menu items from the same INI file. Figure 8 shows these pop-up menus.

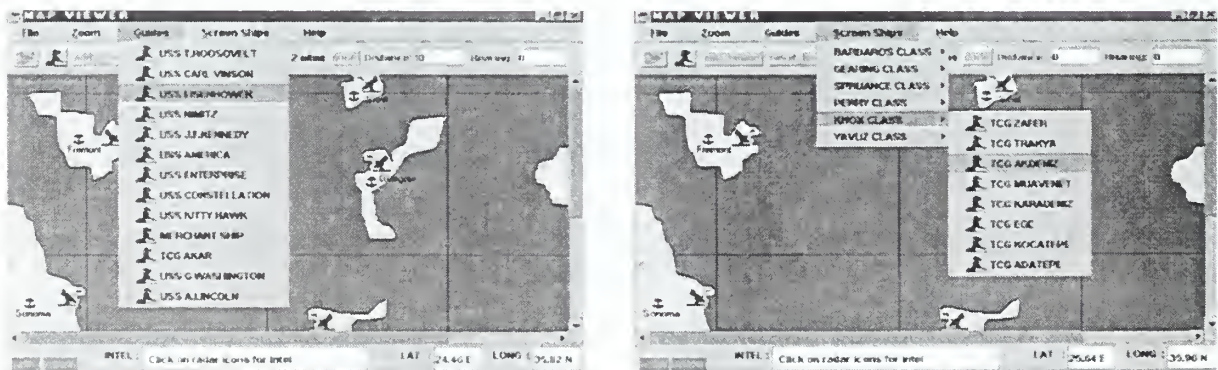


Figure 8. Guides and Screen Ships Menus, each menu is constructed from the INI file.

Ship Explorer allows the user to add new ships to the model as well as to delete them from the model. Deleting one of the ships from the Ship Explorer or adding a new ship to it deletes or adds the unit from or to the associated menu as a menu item. The added item's icon appears in a different color in the menu (Figure 9).

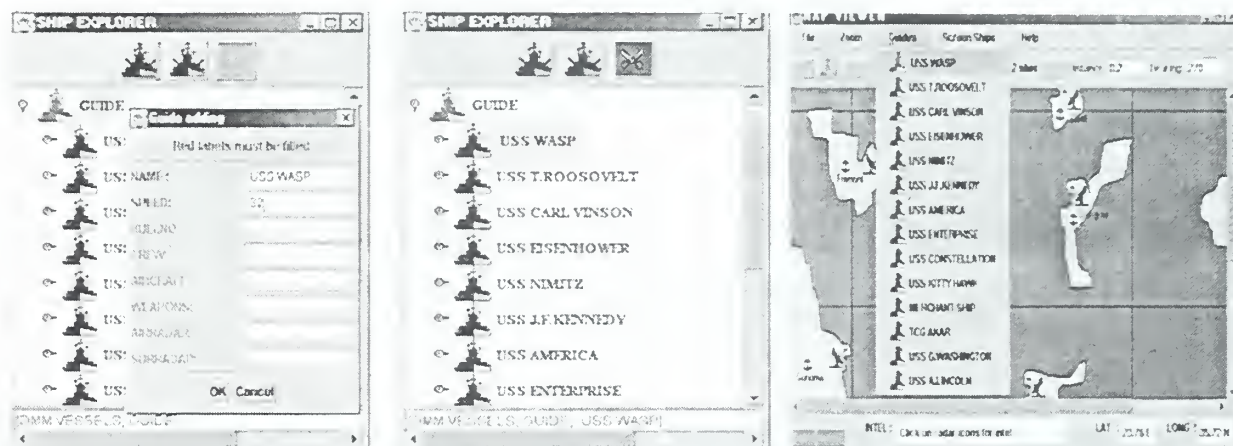


Figure 9. Adding USS WASP to the Guides results in an addition to both Ship Explorer and Guides Menu.

Ship properties in Ship Explorer are editable. If you want a guide to navigate faster, it is easy to edit its speed with one right mouse button click. Figure 10 illustrates this property.

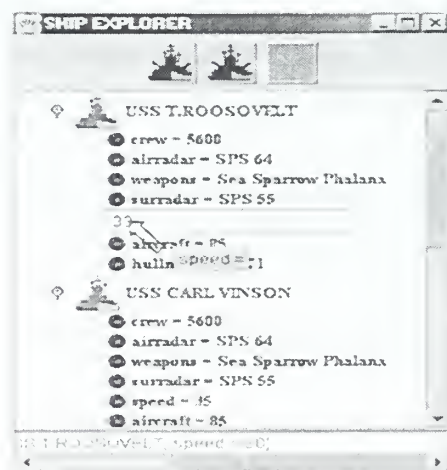


Figure 10. Properties of each ship are editable. The editable text field comes up when clicked using the right mouse button.

All those features described above provide modularity in the model. If a user wants to examine the efficiency of a screen against ASM threats, adding new ships to the Ship Explorer and building the scenario accordingly will make the process very easy. The detailed information about INI files is given in Appendix A.

d. Help Window

The help menu in the main scenario window provides two help items: the version and help. The version shows up as a dialog frame that displays the version of the DMM while help menu item, when selected, brings out a tabbed pane that provides access to many indicies. Figure 11 displays the Help Window.

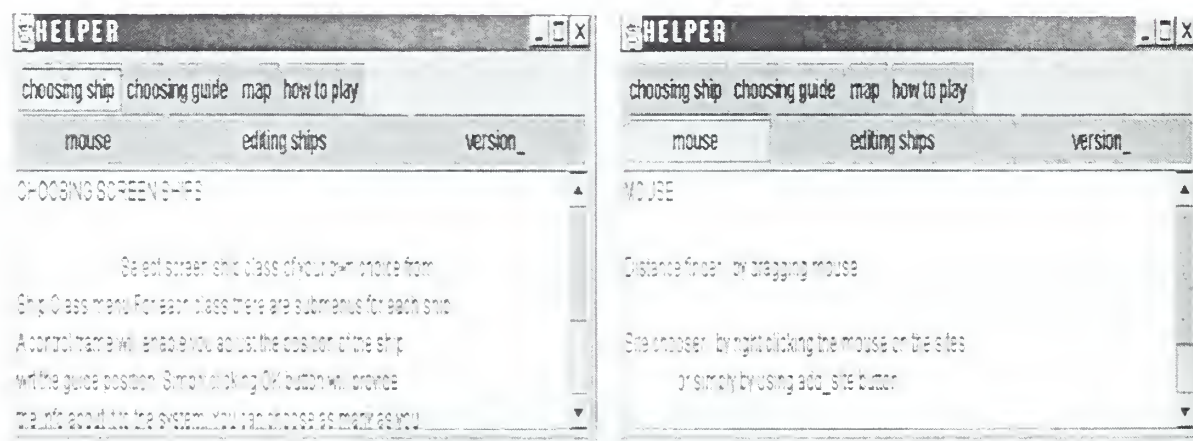


Figure 11. Help Window, with two help headers.

Tabbed panes (JTabbedPane) are a common user interface component in Swing that provides convenient access to more than one panel. The tabs show the name/property of the associated panel. Tab names in this help window are also formed from an INI file (helpTable.ini). The text area of each panel loads a text file whose name is saved in the INI file (Figure 12).

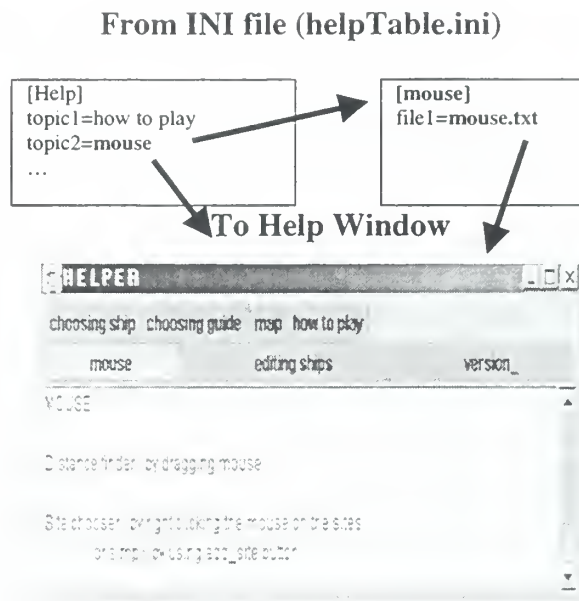


Figure 12. INI File and Help Window

The help window is designed as a tabbed frame in order to maintain modularity. The DMM represents the initial approach to the screen disposition analysis, but the model can be improved in future developments for different purposes. In this development, the help window needs to be updated with new features added to the program. Only new block and key/value pair addition to the INI file (by the new developer) will be enough to update the help window. New added properties will show up as a new tabbed panel in the window.

e. General Features

For Swing, it is particularly important to have a good grasp of “inner classes”, which are used by Swing itself. These inner classes help to write a class inside a class in Java. For listeners such as `actionListener`, `mouseListener`, `mouseMotionListener`, `adjustmentListener`, etc., inner classes are to be implemented. But with this implementation, modularity and flexibility features provided by Java™ can not be used.

Inner class mechanism provides no access for a new class inherited from the outer (main) class in order to overwrite a method of inner class.

GenericAction class originated by Professor Gordon Bradley and Professor Arnold Buss at the Naval Postgraduate School, handles this inner class problem at least for actionListeners used by JButton and JMenuItem. In other words, GenericAction class provides the default functionality of button and menu item methods defined in the AbstractAction class which is an abstract implementation of the Action interface. In the DMM, all buttons and menus are constructed using GenericAction class. The advantage is not only writing a program without inner classes, but also making the buttons and menu items perform accordingly if the action yields the same result. In the DMM, zoomin/zoomout buttons and menu items, when clicked or selected, yield the same result. If one of the components is disabled, then the other is also disabled simultaneously.

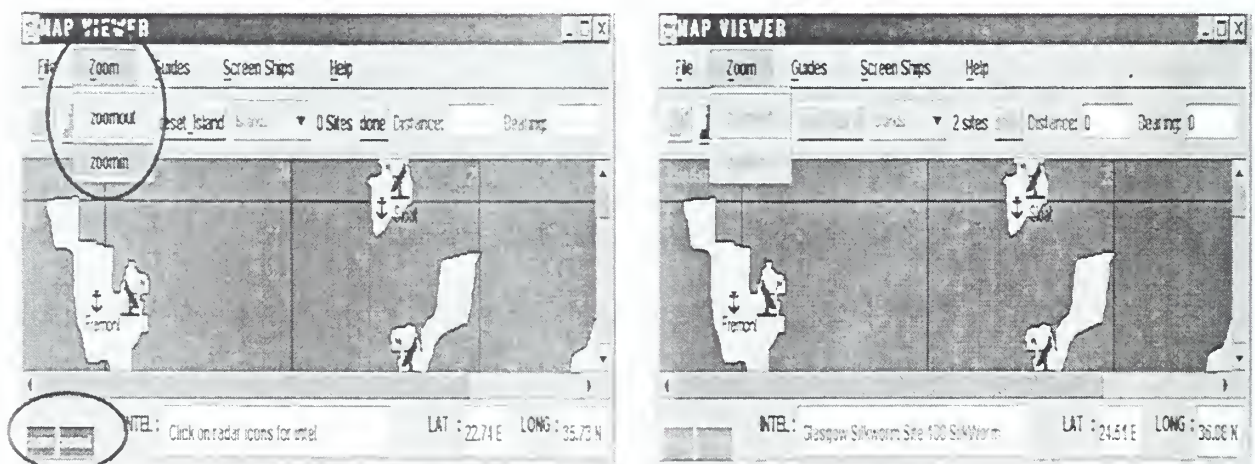


Figure 13. Zoomin/zoomout buttons and menu items are performing the same action and changing their property simultaneously.

2. Simulation Running Window

This window is designed to display a particular part of the map on which the scenario is built, the information about the scenario and the simulation results. The scenario, after being set, is run in the simulation window on which the simulation results are displayed after the run is complete. As seen in Figure 4, the image is related part of the map through which the convoy will navigate. Cropping the original image (map) and then enlarging it by using CropImageFilter and ScaleImageFilter provides this new image. If the scenario is set on a different area of the map, then the window will show that part of the map in a scaled version.

The anchor and wheel buttons, when clicked, display the information about the scenario and the results of the simulation after the last run, in an internal frame (JInternalFrame). Internal frames are windows that can be contained within another container such as a frame on a window. By default, they have close, maximize and minimize buttons like other frames, but all these “standard look and feels” act inside the outer frame. The maximize button, for example, can enlarge the internal frame as large as the container. The Figures 14 and 15 display the internal frames.

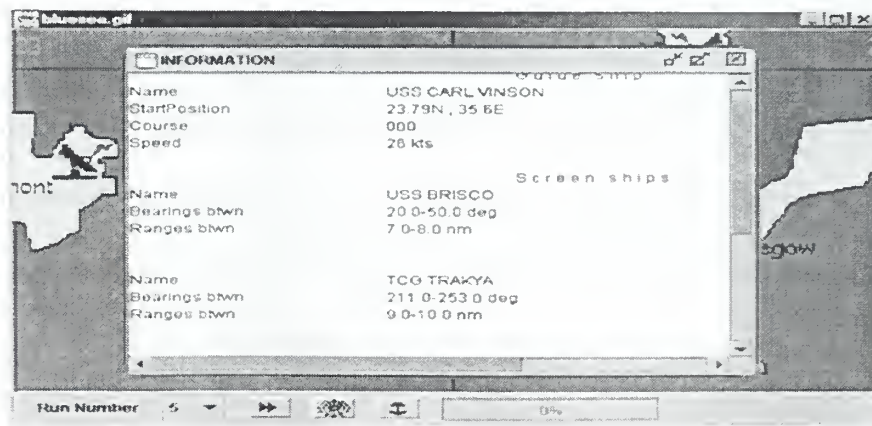


Figure 14. Internal Frame, displaying the information about the scenario

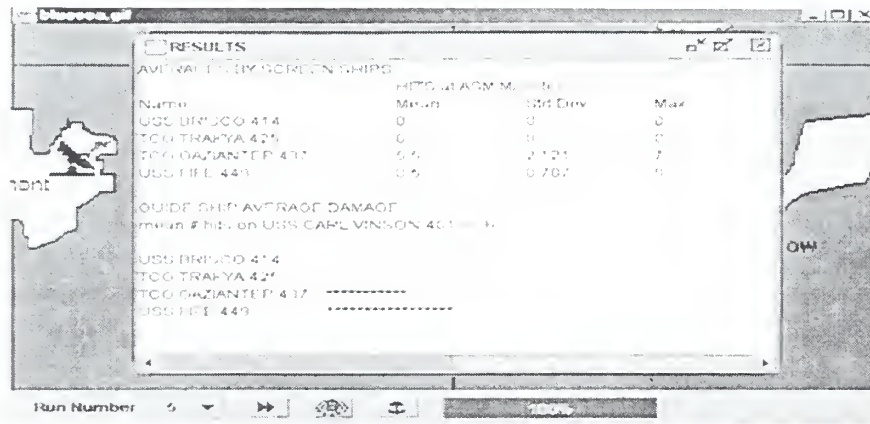


Figure 15. Internal Frame, displaying the simulation results after the fifth run.

When the run button is clicked, the simulation runs the selected number of times.

The simulation part (ASMD) will be covered briefly in the next section.

C. DMM's SIMULATION (ASMD MODEL)

In DMM, the Graphical User Interface is created to provide the ASMD model with a realistic wargame design. The ASMD model was created by James R. Townsend at the Naval Postgraduate School as his Master's Thesis, "Defense of Naval Task Forces from Anti-ship Missile Attack", in Operations Research [Ref. 10].

The model allows for more realistic object movement simulation than regular high-resolution models, owed to a substantial supporting mathematical package. This enhanced realism allows for more accurate simulation of the missile attack. In the scope of this analysis, we will focus only on the most salient points concerning the ASMD model components and their functions in Appendix B. The detailed information and other descriptive functions can be obtained from the original thesis.

D. SUMMARY

The modern interfaces of Java™, together with its flexibility, make the application appealing to the user. In this chapter, we covered how this is possible and fun with Java™.

The DMM's graphical user interface works as a User's Manual, allowing the user to create a scenario of a convoy operation and then make the AAW defense simulation for the related scenario.

In the next chapter we will discuss the simulation results with respect to the appropriate Measure of Effectiveness (MOE) and evaluate the selected MOE by using graphs and regression models.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. ANALYSIS USING DMM

In the previous chapters we have discussed the reasons for creating the Disposition Mission Model (DMM) and how it works. In this chapter we will conduct an analysis using the model.

The DMM was constructed to analyze the effectiveness of different screen dispositions on convoy operations. In order to determine the best arrangement for ships in a TF by using comparative methods, we first need to find the appropriate Measure of Effectiveness (MOE) to make the comparison.

A. MEASURES OF EFFECTIVENESS

In war games, the players are prone to think in terms of the casualties they suffer. The policies and tactics of each side are changed simultaneously by the players as their casualties increase. The loss of an important unit in the force might also change the physical factors that will affect the tactics.

As discussed before, the convoy TF is an assembly of ships responsible for the safe arrival of a special unit (HVU) at its destination. During this passage, the casualties suffered by the screen ships and the HVU will force the OTC to change its tactics in order to minimize damage to the HVU since it is the one to navigate safely. From this point of discussion, counting the number of hits against the HVU is a strong defensive MOE. It quantifies the result that OTC most wants to prevent. In order for this to be the best choice, however, we need to specify what a hit does to an HVU in terms of damage. Three ASM hits might result in a sinking for a merchant HVU while the same number of hits might result in a flight platform damage for an aircraft carrier; but not a sinking.

Thus, in order not to confuse the decision-maker in terms of damage criteria of each different HVU, and not to focus the user on the damage of the HVU neither in equipment nor territory criteria, only the percentage hits on the HVU will be analyzed. If the ASM sites deliver 30 ASM's, and the mean number of hits on the HVU is 4, then the percentage hit on the HVU will be $\frac{4}{30} = 0.133$ (13%). It will later be clear that this also helps in analysis using logistic regression.

B. INITIAL SCENARIO

We will start the analysis with a simple scenario: the defense of an HVU using one screen ship against one ASM site (Figure 16). This scenario will also provide the initial approach into how we evaluate the MOE that has been selected.

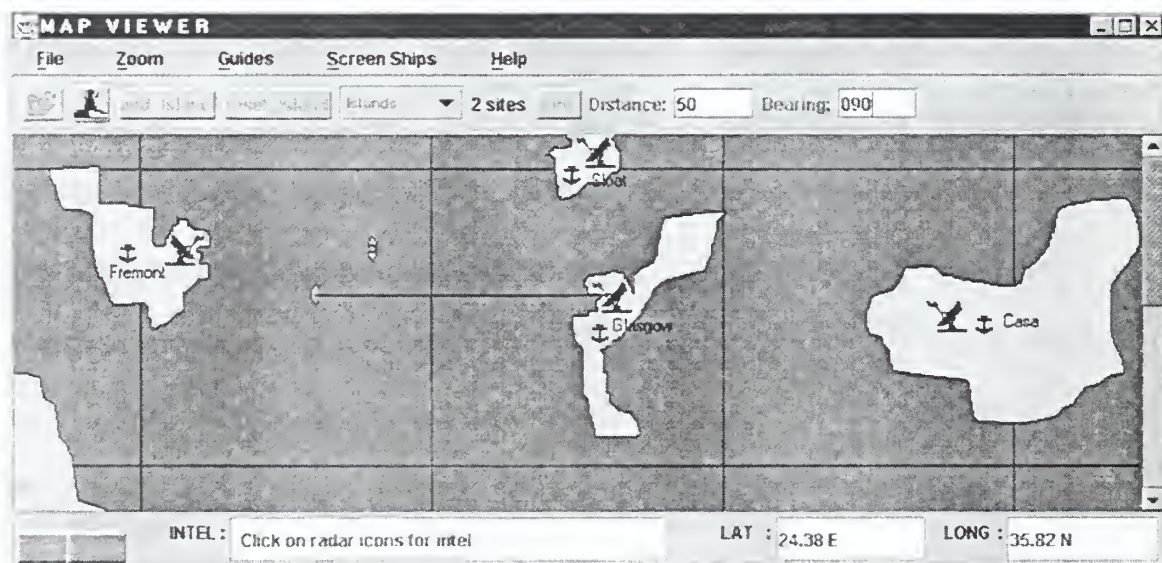


Figure 16. Main Scenario Window, displaying a convoy with one HVU and a screen ship to protect the HVU against one ASM site whose bearing is 090° true and distance is 50NM from the HVU.

The details of the scenario are:

- The HVU is 50 NM west of the ASM site (ASM site's bearing is 090 true from the HVU)

- The ASM site delivers 30 Silkworm missiles towards HVU
- A Spruance class screen ship is positioned from 000° to 180° (with increments of 10°) in bearing and from 1 to 45 NM (with increments of 2 NM) in range.
- Each new position scenario is run 20 times (each of which lasts about 12 minutes in a Pentium® III processor PC).

1. Range and Bearing Factors

As already stated, the general screen disposition method is used in the DMM in which each screen ship is positioned with respect to the HVU in range and bearing terms. Figure 17 illustrates the MOE vs. bearing and range. In the left panel (bearing), the screen ship is positioned from 000° to 180° with increments of 10° in every range from 1 to 45 NM with increments of 2 NM.

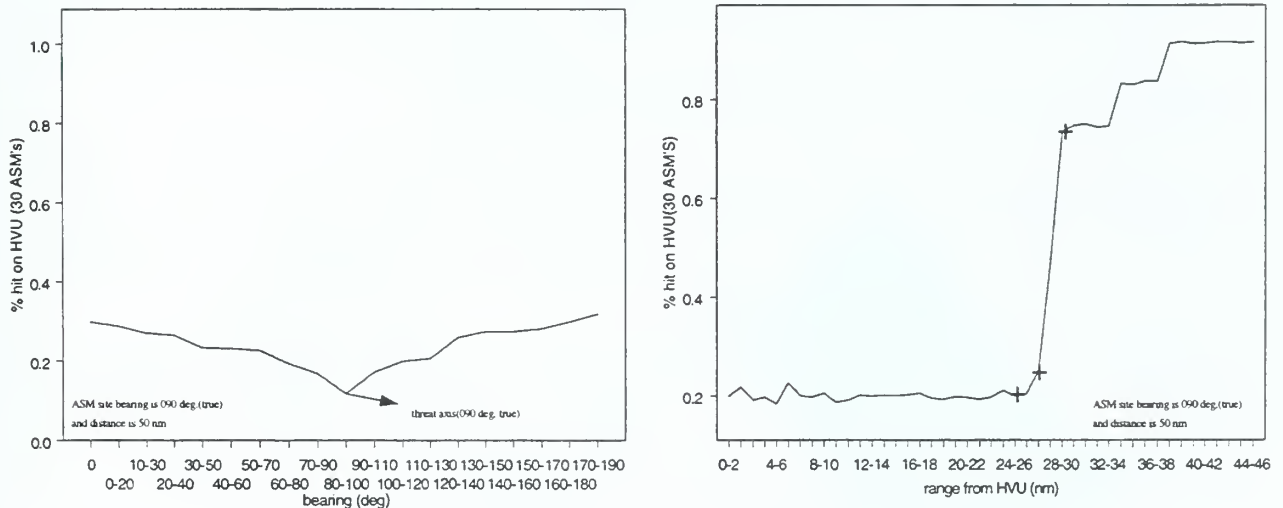


Figure 17. The graph displaying the percentage hits on HVU for possible ranges and bearings of screen ship.

The smallest percentage value occurs when the screen ship is put between 080°-100°, and as seen in the left panel of Figure 17, the percentage hit value on HVU starts increasing as the screen ship is positioned away from that sector. The defense works pretty well on 080°-100° sector since the Silkworm missiles are coming from that sector (090° is the threat axis).

In the right panel (distance), the screen ship is positioned from 1 to 45 NM with increments of 2 NM in every bearing from 000° to 180° with increments of 10°. The percentage hit value starts increasing when the screen ship is positioned farther than 25 NM away from the HVU (25 NM is the weapon guidance range limit for a Spruance class frigate). Using different types of screen ships, it is seen that for best results HVU must be covered at least within the screen ship weapon range.

Figure 18 displays the results in a three-dimensional way using a surface grid and a histogram box plot. As seen from both panels in Figure 18, regardless of range factor, which changes for each type of ship, placing the screen ship on the threat axis (090° here) undoubtedly seems the best choice for the decision maker.

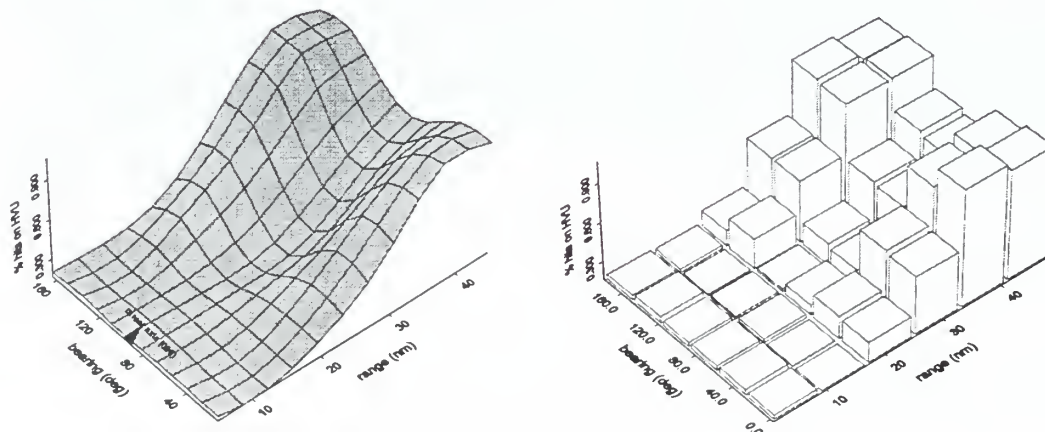


Figure 18. 3-dimensional surface grid and histogram graph displaying the percentage hits on an HVU for different ranges and bearings.

2. Regression Analysis

As discussed in the first chapter, regression summarizes (or models) complex data in a compact way, while evaluating evidence for a theoretical claim that there might be covariation between variables [Ref. 13]. Analysis is now conducted to determine whether a systematic (non-chance) covariance between the percentage-hit value on HVU and location values of the screen ship (range/bearing) exists, by way of regression analysis.

Using linear regression methods, our model for this scenario will be:

$$\text{percentage}_i = \beta_0 + \beta_1 \text{range}_i + \beta_2 \text{sector}_i$$

where $i=1,2,3,\dots,n$ (number of observations) and $\beta_{0,1,2}$ are the coefficients.

The range variable is the actual distance in nautical miles between the HVU and the screen ship. The sector variable is coded 1 if the screen ship is positioned on the threat sector, 0 otherwise. The threat sector is considered to be 30° on both sides of the actual threat bearing. For the above example, the threat bearing is 090° ; causing the threat sector to be a sector between 060° - 120° .

The percentage-hit value is always between 0.0 and 1.0. 0.0% indicates that HVU gets no hits from the ASM raid while 100% explains a very bad defense formation in which all missiles hit the HVU. In regression analysis this kind of variable is called a categorical variable. Categorical variables require different approaches rather than linear regression methods. Logit regression is the most widely known alternative to linear regression in this circumstance. In practical use, ordinary regression methods and the logit regression method have many similarities, although their underlying mathematical bases are different. The detailed information about logit regression is beyond the scope of this thesis, and may be found in many statistics textbooks. In short however, it is valuable

to know that logit regression prevents the percentage value from exceeding 1.0 and falling below 0.0. The values beyond these limits will be impossible predictions derived from reasonable locations of the screen ship.

The new model, using logit regression, will be:

$\text{Logit}_i = \beta_0 + \beta_1 \text{range}_i + \beta_2 \text{sector}_i$ where $i=1,2,3,\dots,n$ (number of observations), $\beta_{0,1,2}$ are the coefficients and the percentage-hit value will be computed as $\text{percentage} = \frac{1}{1 + e^{-\text{Logit}}}$. By using S-PLUS, the calculated coefficients are $\beta_0 = -2.277822$, $\beta_1 = 0.1064937$ and $\beta_2 = -0.7963955$.

Thus, our model becomes:

$\text{Logit}_i \approx -2.3 + 0.1 \times \text{range}_i - 0.8 \times \text{sector}_i$ and percentage hit value is $\frac{1}{1 + e^{-\text{Logit}}}$.

As an example, if the screen ship is 10 NM away from the HVU with a true bearing of 110° , which is within the threat sector, then $\text{Logit}_i \approx -2.3 + 0.1 \times 10 - 0.8 \times 1$ becomes -2.1 and the percentage hit value becomes $\frac{1}{1 + e^{-(-2.1)}} = 0.11$ (11%). This is a very good prediction since the true value is actually 12% when we position the screen ship 10 NM away from the HVU with true bearing of 110° using DMM.

The Figure 19 shows the graph of percentage hits on the HVU versus fitted values derived from the logit regression. The logit regression line covers most of the data points on the graph, which means that logit regression works for this simple scenario.

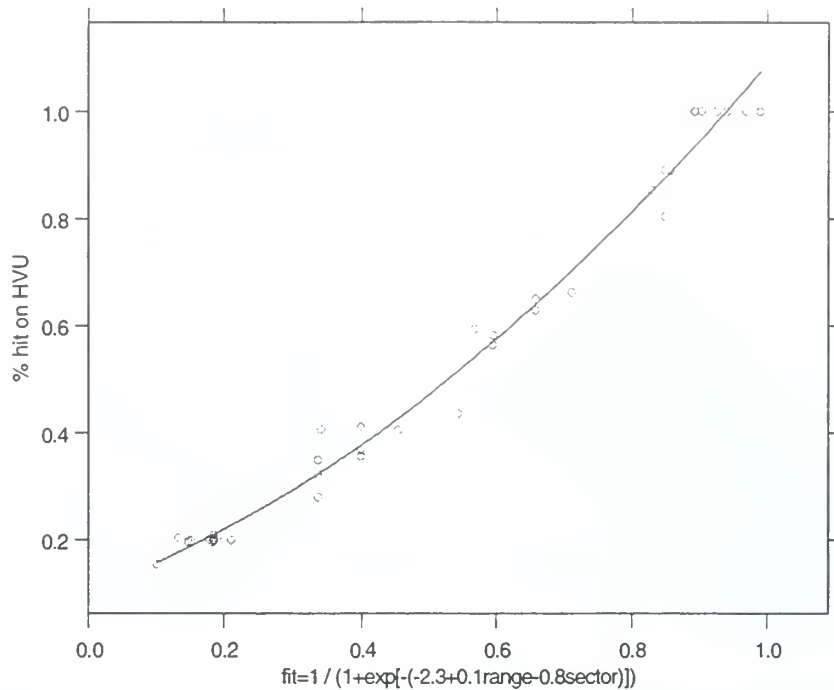


Figure 19. Graph of percentage hits on the HVU versus fitted values derived from logit regression.

As we try to work on some detailed and complex examples (developed scenarios) in later sections of this chapter, more complex formulations and models will be considered using more variables, such as the number of ships, total range, and number of ASM sites, rather than only range and sector variables. However, in dealing with more variables we may encounter some statistical problems, such as zero effect variable or multicollinearity between variables. The methods to eliminate these problems will also be evaluated in this chapter.

3. Improved Scenario

This scenario differs from the above scenario only with an addition of an extra ASM site. The true bearing of the new site is 270° from the HVU and both ASM sites have 15 Silkworm missiles, for a total of 30 missiles. Now a convoy consisting of one

HVU and one screen ship will try to navigate between two sites, one of which is on the east and the other on the west side of the convoy. Figure 20 graphs the results in a three-dimensional way using a surface grid and a histogram box plot.

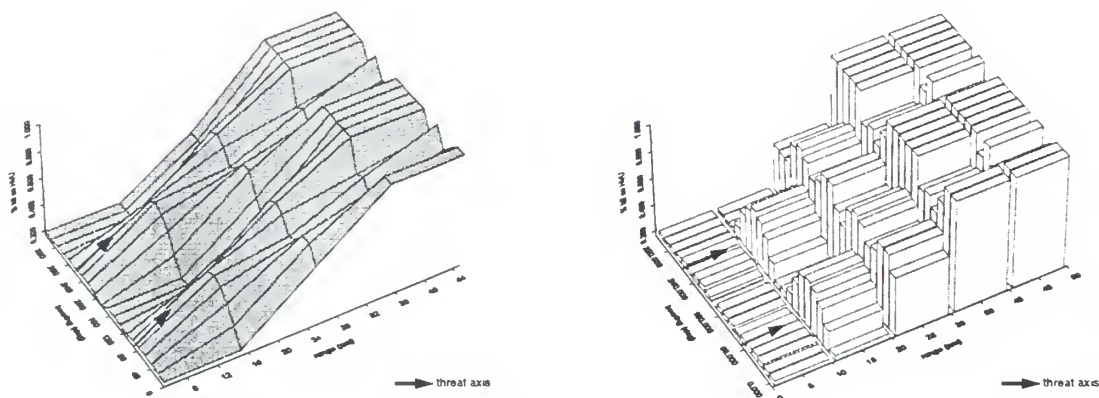


Figure 20. 3-dimensional surface grid and histogram graph displaying the percentage hits on the HVU for different ranges and bearings of the screen ships against two ASM sites.

As seen from the above panels, the screen ship that is positioned within 10 NM of the HVU (regardless of the bearing), due to its effective weapon guidance coverage within this distance, defends effectively against the incoming missiles from both sites. But within ranges of 10 to 25 NM, the damage on the HVU increases if the screen ship is positioned on the threat axes, in particular 090° and 270° ($\pm 10^\circ$). In these ranges, the least damage occurs when the screen ship is 000° and 180° ($\pm 10^\circ$), which are mid-bearing values of the two threat axes. As the distance between the HVU and the screen ship increases, it looks better if the screen ship is placed on one of the threat axes because it becomes impossible for the screen ship to cover the HVU for the incoming missiles from both sites. Thus, in long distances, it is better to focus on the missiles coming from one site by positioning the screen ship on that threat sector. Positioning the screen ship on

any other sector at long distances will have the screen ship miss more of the missiles coming from both sites.

C. OTHER SCENARIOS

1. Two Screen Ships vs. Two ASM Sites

In this scenario, there are two screen ships to protect the HVU against the missiles from two ASM sites, each of which has 30 Silkworm missiles to fire. The ASM sites' bearings are 090° and 270° true and they are 50 NM away from the HVU. We will analyze three different situations:

- Both of the screen ships are on the threat sector ($\pm 30^\circ$ from the threat axis)
- One of the screen ships is on the threat sector while the other is not.
- None of the screen ships are on the threat sector.

Figure 21 illustrates the graph of percentage hits vs. total distance between screen ships and the HVU (sum of the distances between each screen ship and the HVU).

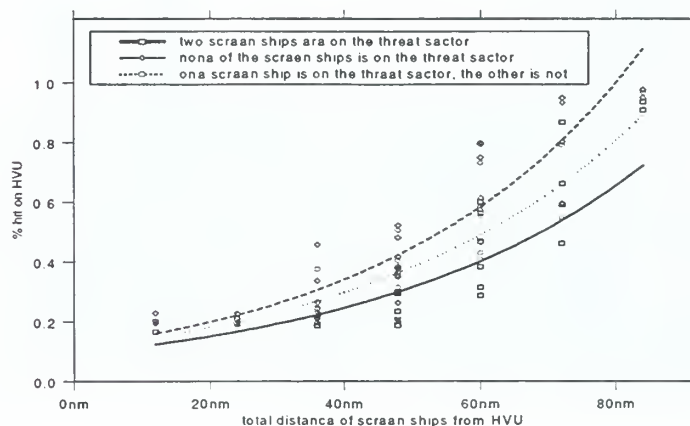


Figure 21. The scatter plot graph of percentage hit vs. total distance between screen ships and the HVU together with regression lines for each situation. Positioning the screen ships on the threat sector provides more effective defense against the incoming missiles.

Figure 21 displays both scatter plots of the actual data points and the linear regression lines related with these data points. The regression lines provide a better comparison for these three situations than the individual points in the graph. As seen from the fitted lines on the above graph, the more screen ships placed out of the threat sector, the less effective the defense shield is in defending the HVU. However, this comparison would be too hard to make with the scatter plot.

Positioning more ships on the threat sector provides not only a better defense, but also a reduction in “incoming missile per screen ship rate”. Thus, as more screen ships are positioned outside the threat sector, the number of missiles they have to kill (homing missiles towards them) increases. Since the screen ship is far away and out of the threat sector and consequently cannot cover its own missiles, the other screen ship has to intercept with more inbound missiles (more than 30) from both sites. Figures 22, 23, and 24 show this increment for three different situations in frequency histogram plots. The location term in the x-axis of each graph indicates that the screen ships are put on 32 different locations. In Figure 22, for example, both screen ships are positioned on 32 different locations on their threat sectors while in Figure 23 ships are positioned in the same number of locations but with one screen ship on the threat sector and the other out of the threat sector. In each location point of these three graphs the distance between the screen ship and the HVU remains the same. For example, in the first location in Figure 22 the distance between one of the screen ships and the HVU is 6 NM and the distance between the other ship and the HVU is 12 NM, and both are on their threat sectors. However, in Figure 23 the distance values remain the same (6 NM and 12 NM) for the first location, but one of the screen ship is on the threat sector and the other is not. This is true for the locations one through thirty-two with different distance values.

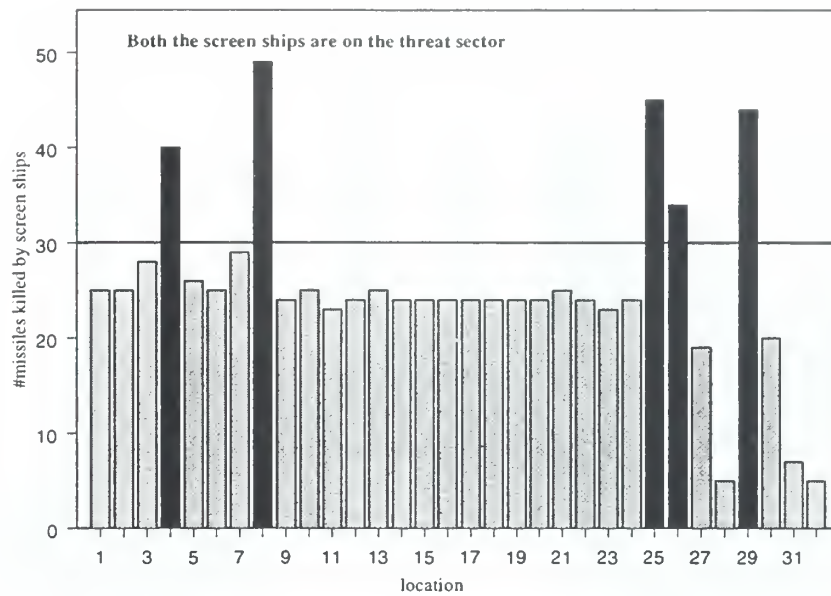


Figure 22. The frequency histogram graph showing the efforts both screen ships spend when positioned on the threat sector. The darker bars indicate that they have to defend more than 30 missiles only five times.

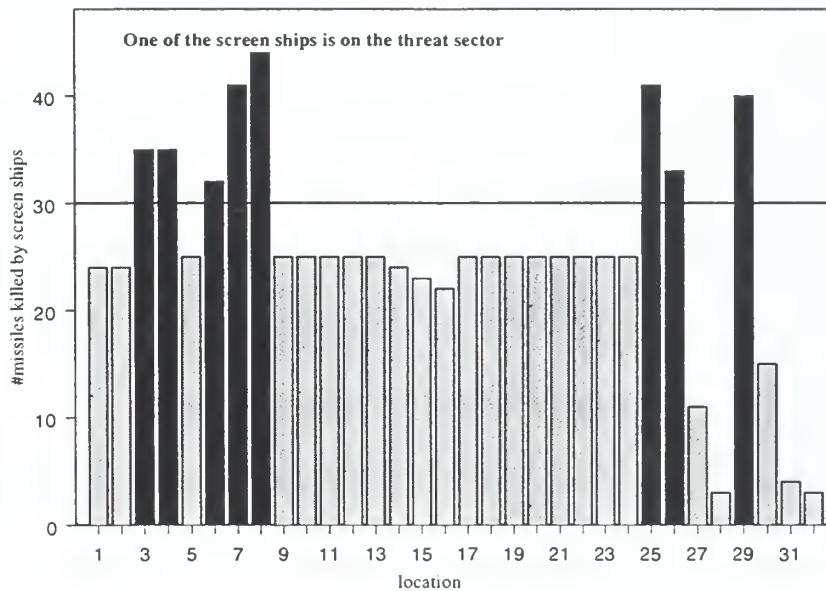


Figure 23. The frequency histogram graph showing the efforts both screen ships spend when positioned one on the threat sector and the other out of the threat sector. They have to defend more than 30 missiles eight times.

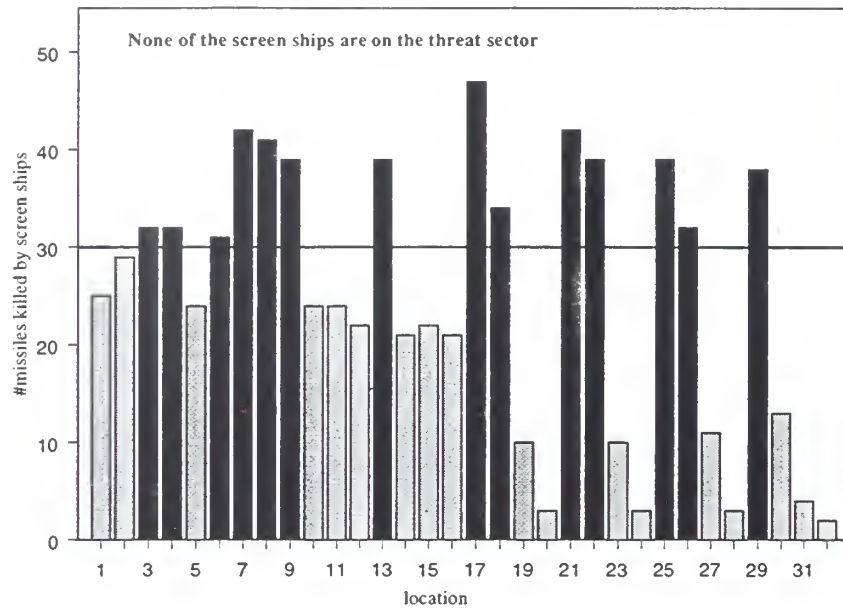


Figure 24. The frequency histogram graph showing the efforts both screen ships spend when positioned out of the threat sectors They have to defend more than 30 missiles fourteen times.

When each ASM site fires 30 missiles, the optimum defense tactic is to let each screen ship intercept those 30. As seen in the Figure 22, in situations when screen ships are on the threat sector, they have to defend more than 30 missiles only five times. But if at least one screen ship is on off-threat sector, the screen ships have to deal with more than 30 missiles more than five times - eight and fourteen times respectively (Figures 23 and 24).

2. Three Screen Ships vs. Two ASM Sites

The last scenario is now improved by adding one more defense ship and increasing the number of ASM missiles at Silkworm sites. This time there are three screen ships to protect the HVU. The ASM sites' bearings are 090° and 270° and each of the sites has 60 Silkworm missiles to fire against the HVU. Two of the screen ships are

put on the threat sector and the third one is positioned from 000° to 360° in bearing with 10° increments and 1 NM to 45 NM in range with 10 NM increments. Figure 25 shows the MOE vs. range and bearing graphs in the three-dimensional surface grid and histogram box plots.

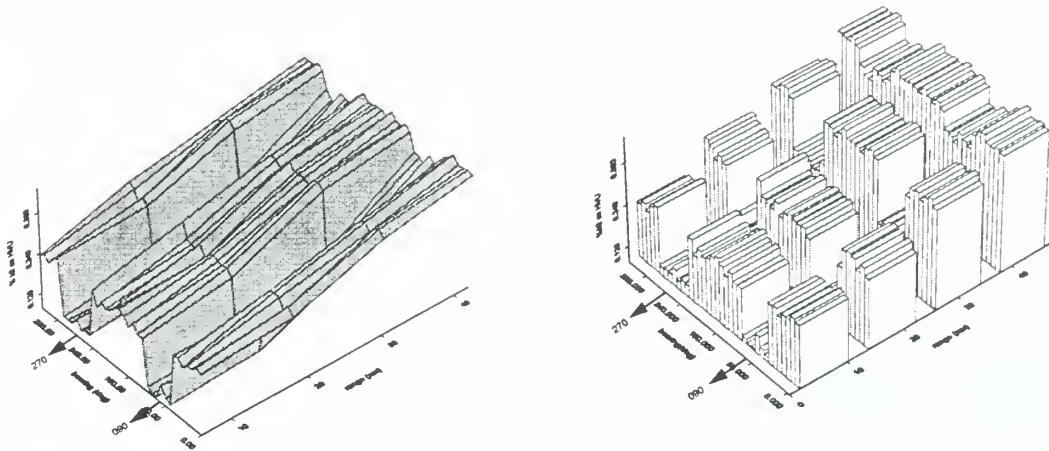


Figure 25. 3-dimensional surface grid and histogram graph displaying the percentage hits on the HVU for different ranges and bearings.

As seen from the graphs, since we have three ships (two of which are on the threat sector) the percentage-hit value is below 0.36, which shows a better defense compared to one or two ship examples. The percentage hit value changes with respect to the third ship's location. The percentage value decreases when the third screen ship is on the threat sectors and the value stays the same in every bearing inside the sector ($\mp 30^\circ$ from the threat axes). When the screen ship is positioned on the threat sector, it not only provides a good defense shield, but it also accompanies the other screen ship that is on the same threat sector by taking over the responsibility for some of the missiles coming from that sector. For instance, the screen ship A is on the threat axis 090° and manages to kill 25 missiles out of 60. But if we put another screen ship B within the same threat

sector (between 060° and 120°), it is observed that they totally kill about 43 missiles and both share the missile load almost evenly at 21 and 22 each. Thus, the burden on the screen ship A is now 4 missiles less.

D. DETAILED REGRESSION ANALYSIS

In the previous attempt to derive a relationship between the percentage hit value and range/sector variables, it was demonstrated how and why logit regression should be used in the model. The logit regression formulation derived was related with a simple scenario, but more complex scenarios require a more complex logit model. In the later scenarios the number of ASM sites and the number of screen ships were increased and a new ASM site addition to the system changed the number of missiles fired against the convoy and added one extra threat axis to the model. The addition of screen ships provided the model with different sub-scenarios by positioning them on the threat sector at different ranges. All those changes introduced new variables (such as number of missiles, number of threat axes, total distances between screen ships and the HVU when the screen ship is on the threat sector and when it is not) into the model. Thus, as an initial approach, the regression model is set as:

$$\text{Logit}_i = \beta_0 + \beta_1 \text{rangeon}_i + \beta_2 \text{rangeoff}_i + \beta_3 \text{missiles}_i + \beta_4 \text{shipson}_i + \beta_5 \text{ships}_i + \beta_6 \text{axis}_i$$

where **rangeon**: total range of screen ships on the threat sector from the HVU
rangeoff: total range of screen ships out of the threat sector from the HVU
missiles: number of missiles fired from the ASM sites
ships: total number of ships
shipson: number of ships on the threat sector
axis: number of axes

Since the total number of missiles fired on the HVU is being used in the calculation of the percentage value, we can eliminate this variable from the model. The number of axes is also used in “rangeon” and “rangeoff” variables and can cause

“multicollinearity” (high correlation between X variables). Thus, the axis variable can also be eliminated from the model. With these two variables gone, the model is now:

$$\text{Logit } i = \beta_0 + \beta_1 \text{rangeon } i + \beta_2 \text{rangeoff } i + \beta_3 \text{shipson } i + \beta_4 \text{ships } i$$

By using S-PLUS, we get the statistics of the coefficients in our model:

| n=284, df=279 | Value | Std. Error | t value | P-value |
|------------------------|-------------|-------------|-----------|---------|
| Intercept(β_0) | -0.39309453 | 0.510680834 | -0.769746 | |
| β_1 | 0.03882233 | 0.009271491 | 4.187280 | <0.005 |
| β_2 | 0.05374549 | 0.013484903 | 3.985604 | <0.005 |
| β_3 | -0.03360942 | 0.294809156 | -0.114004 | >0.500 |
| β_4 | -1.01454511 | 0.308877460 | -3.284620 | <0.005 |

Table 1. Logit Regression of percentage hit on HVU.

A step is now taken to ensure that these coefficients have the proper effect on the response variable, that is, they are not zero. If they are zero, then they are not needed in the model. In order to know this, a hypothesis test is conducted on the coefficients.

1. Hypothesis Test

$$H_0: \beta_k = 0$$

$$H_1: \beta_k \neq 0$$

where $k = 0, 1, 2, 3, 4$

In Table 1, P-values are obtained from student t-statistics tables for two sided tests with $284 - 5 = 279$ degrees of freedom. These P-values show that all of the variables except “shipson” (number of ships on the threat sector) have coefficients significant at $\alpha=0.05$. Thus, the null hypothesis can be rejected for all coefficients except β_3 . And by failing to reject the null hypothesis for this coefficient, it is concluded that β_3 has no effect on the model.

Without the shipon variable, the new model is:

$$\text{Logit } i = \beta_0 + \beta_1 \text{rangeon } i + \beta_2 \text{rangeoff } i + \beta_3 \text{ships } i$$

By using S-PLUS, the statistics of the coefficients in the new model are:

| n=284, df=279 | Value | Std. Error | t value | P-value |
|------------------------|-------------|-------------|------------|---------|
| Intercept(β_0) | -0.37007626 | 0.469053657 | -0.7889849 | |
| β_1 | 0.03859041 | 0.009041703 | 4.2680469 | <0.005 |
| β_2 | 0.05458885 | 0.011301562 | 4.8302042 | <0.005 |
| β_3 | -1.05374942 | 0.221938280 | -4.7479390 | <0.005 |

Table 2. Logit Regression of percentage hit on HVU.

By checking P-values in Table 2, the null hypothesis is rejected that all coefficients do not have zero effect on the percentage-hit variable (response variable) at significance level $\alpha=0.05$.

It has also been seen that the combination of the shipon variable (the one that was eliminated) with other variables actually does not bring a significant improvement into the latest model fit.

$$\text{Logit } i = -0.37 + 0.039 \text{rangeon } i + 0.055 \text{rangeoff } i - 1.054 \text{ships } i$$

The regression formula of the model becomes:

$$\text{fit : percentage } i = \frac{1}{1 + e^{-(-0.37 + 0.039 \text{rangeon } i + 0.055 \text{rangeoff } i - 1.054 \text{ships } i)}}$$

Figure 26 illustrates the regression fit graph. The regression line covers most of the data points, revealing a good fit.

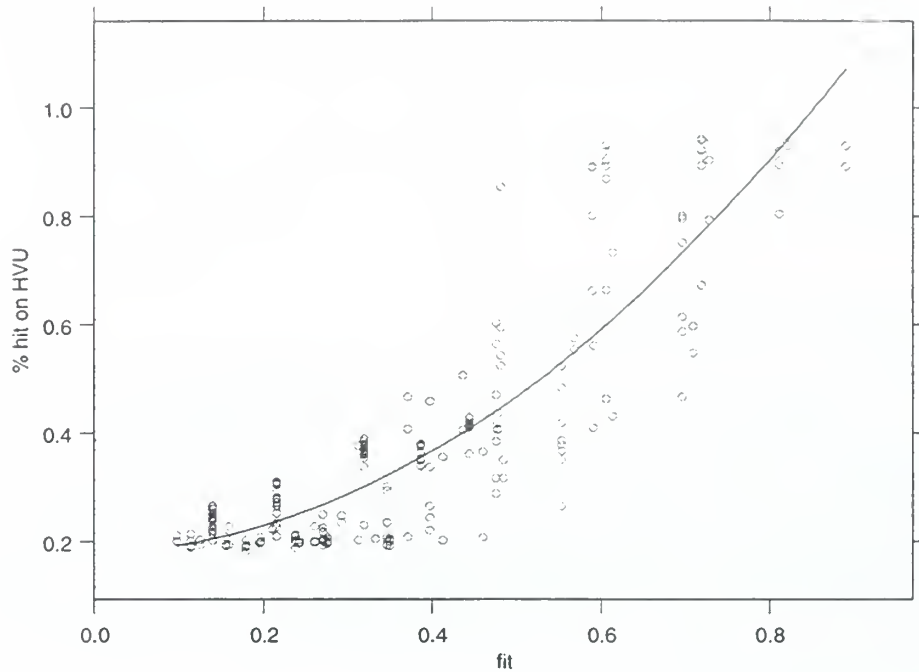


Figure 26. Graph of percentage hit on the HVU versus fitted values derived from logit regression.

2. Interpretation

The logit equation from Table 2 is approximately:

$$\text{Logit } i = -0.37 + 0.039 \times \text{rangeon } i + 0.055 \times \text{rangeoff } i - 1.054 \times \text{ships } i$$

where rangeon is the total distance between the ships on the threat sector and the HVU, rangeoff is again the total distance between ships off the threat sector and the HVU, and ships variable indicates the number of screen ships in the convoy.

This formulation is intended to find the conditional effects of each variable on the percentage-hit value. Since the input variables are not accurate due to their classified status, the results from this formulation might not always compute the actual damage on the HVU.

Each coefficient with reference to the percentage-hit value can now be interpreted. For rangeon variable, with each additional 1 NM total distance of screen ships on the threat sector from the HVU, all other variables being at their averages, the predicted logit is now:

$$\hat{\text{logit}}_i = -1.8 + 0.039 \times \text{rangeon}_i$$

The linear relationship between rangeon and predicted logits implies a curvilinear relationship:

$$\hat{\text{percentage}}_i = \frac{1}{1 + e^{-(-1.88 + 0.039 \times \text{rangeon}_i)}}$$

The relationship between rangeoff variables and the percentage hit values changes

$$\text{with } \hat{\text{percentage}}_i = \frac{1}{1 + e^{-(-1.75 + 0.055 \times \text{rangeoff}_i)}}.$$

For instance, for every new ship addition to the convoy, with the other two variables having their average values (18 and 28 for rangeon and rangeoff respectively), the following predicted logit equation is now determined:

$$\text{Logit}_i = 1.72 - 1.054 \times \text{ships}_i$$

And the curvilinear relationship between number of ships and the percentage-hit

$$\text{value implies } \hat{\text{percentage}}_i = \frac{1}{1 + e^{-(1.72 - 1.054 \times \text{ships}_i)}}. \text{ Figure 27 illustrates the}$$

conditional effects of each variable at average levels of the remaining variables.

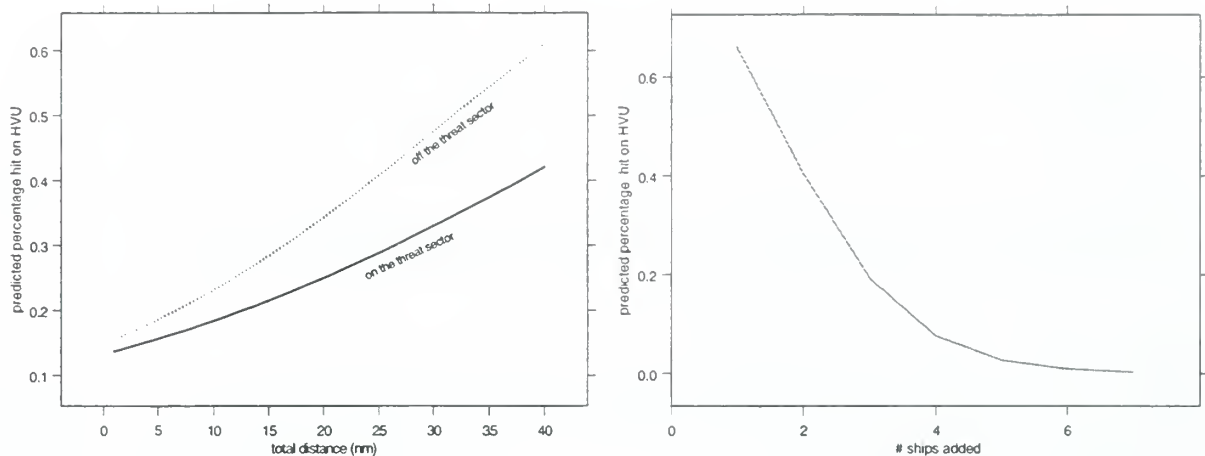


Figure 27. Conditional effects of range and number of ship variables at average levels of the other variables. (Left panel) As the screen ships are placed farther from the HVU, the conditional effect on the percentage damage increases, but a larger effect appears for the screen ships out of the threat sector. (Right panel) If the convoy is provided with more ships, the conditional effect decreases curvilinearly.

From the graphs in Figure 27, it is easy to interpret that the number of ships has the most effect on the percentage-hit value with range on the second most effective.

E. TACTICS

In the preceding chapter it was pointed out that the screen ships' (effective) positioning for the defense against the land-based AAW threats could provide successful work for the safety of the convoy. For some small navies that can not provide more defensive ships per HVU, the advantages of effective positioning become very important.

Vessels for convoy operations do not have to be many in number; in fact, for much of the work in minefields, which is another big threat in the littoral arena, it would be better to have fewer ships by reason of reducing "the ships per mine ratio." In a multi-threat arena or during a conventional war, it would seem necessary to have fewer but effectively coordinated ships per mission. Otherwise, gaining one and losing more would not yield an appropriate balance in the war effort.

The DMM has yielded significant insights towards the defense of a convoy. It is seen that effective positioning of the escort ships reduced the damage on the HVU and also balanced the defensive load of each defense ship for the incoming missiles. The following are some scenarios that will help to interpret what has been seen so far.

1. Range vs. Bearing

It has been shown that screen ships, regardless of their distances from the HVU, should be on the threat sector when they are to defend against more than one ASM site. This is especially important for emergency reactions, where taking positions on the threat sector takes less time than positioning on the distance necessary for effective weapon coverage range. Figure 28 shows a similar scenario.

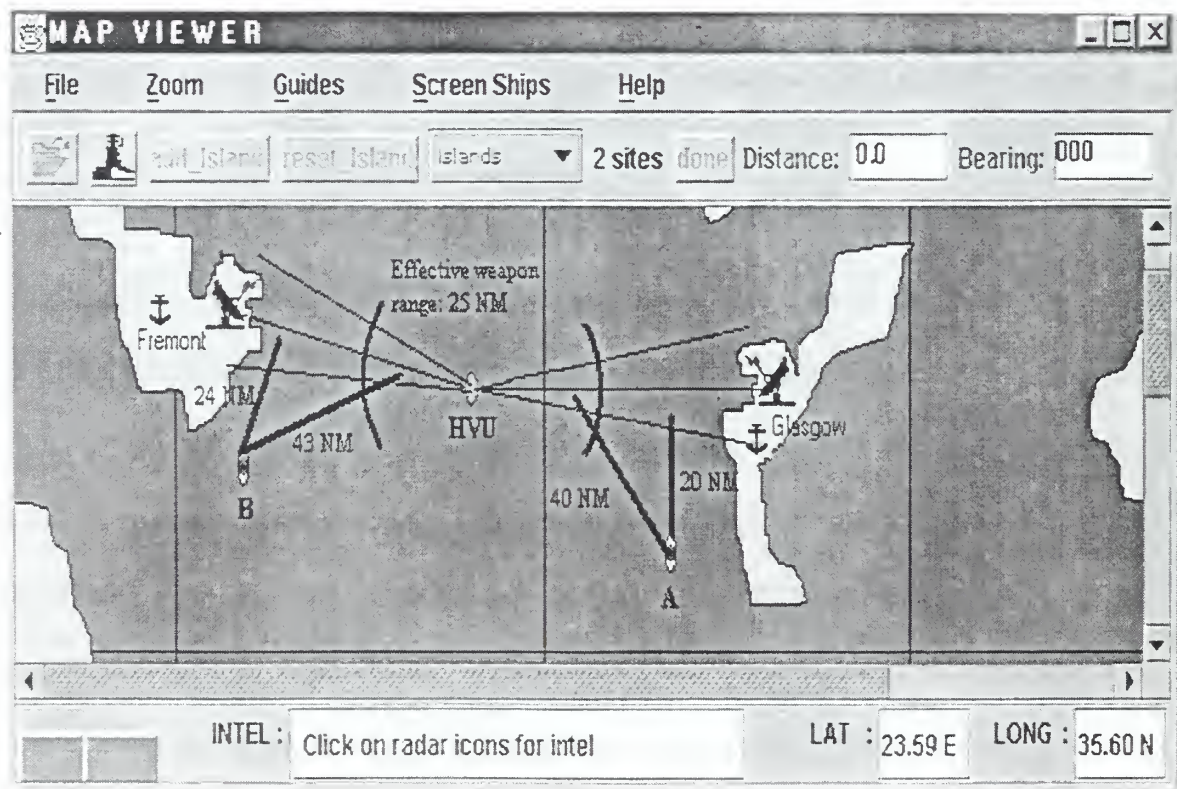


Figure 28. The Main Scenario Window, displaying a scenario. For quick maneuvers the delay resulted from taking positions on the threat sector or inside the effective weapon range might be very important since the attack might come any minute.

As seen from the above picture, the screen ships A and B must move to their defensive locations. But assuming that their maximum speeds are 30 kts., they position in their threat sectors about 20 minutes earlier than the time they position on their effective weapon guidance range and start defending. This time delay might be important if it is unclear about the exact time the attack starts. In the preceding chapter it was also shown that a screen ship within the threat sector could provide a defense as effective as being on the effective weapons range.

In the last part of the regression modeling, it was also seen that being within the threat sector affects the defense more positively than being on the effective range (Figure 25 left panel).

2. More Than One Ship On Threat Sector

If more screen ships exist than the number of threats, the remaining ships must also be positioned on the threat sector. This positioning brings along two advantages to the defense: less damage on the HVU and a reduction in the incoming missiles per screen ship rate.

For the ranges explored, the threat sector is $\pm 30^\circ$ from the threat axis. And in Figure 25, it was seen that the damage percentage on the HVU did not change as long as the extra ship was in that sector ($\pm 30^\circ$ from the threat axis). Thus, assuming that there might be other threats from other directions, the extra screen ship should be positioned on the outer sides of the threat sector. For a threat axis with a true bearing of 090° , one ship on the exact threat axis and the other one on the 120° or 060° (according to possible other attacks direction) is more effective. This positioning also helps the screen ships in defending fewer missiles while the convoy as a whole makes a more effective defense (Figures 22, 23, and 24).

F. SUMMARY

The prominent trend in war games is away from cover, deception and dispersion of a TF, and toward essential tactics to survive and perform the duty. If this duty is to protect a valuable unit, which is the core of the ongoing operations, then the players focus on the tactics to build a concentrated force to defend this unit against the hostility.

In this chapter, a method was explored for analyzing the effectiveness of various defensive options in enhancing the safety of the HVU. For the survivability issue of the HVU, the percentage hits on the HVU is deemed to be an appropriate MOE.

A simple scenario was begun and built upon with more complex examples in order to make a comparative analysis of the MOE. The regression analysis was introduced to study the conditional effects of the range, bearing and the number of ship variables in the model.

The analysis proved how to form an effective positioning by examining the results derived from the conditional effects of each input in the regression model. It was seen that positioning the screen ships on threat sector would be the effective disposition resulting in less damage on the HVU against the ASM's. Two main results derived from the threat sector-positioning tactic are as follows:

- Reduction in the damage of the HVU.
- Reduction in the weapon load of each screen ships.

The overall conclusions and recommendations for future tactics will be discussed in the next chapter.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

In this thesis, we have sought to explore an analysis tool in the area of screen defense of a convoy against the land-based ASM's.

The Graphical User Interface (GUI) has yielded a significant capability to simulate a battle space with all entities (ships, sensors, missiles etc.) necessary to form a convoy screen and the hostile elements.

The simulation part of DMM (ASMD model) has proved to be sufficient to simulate an exact model of a battle scenario by the help of a very sophisticated mathematical package. Thus, the movement of each entity in the model is designed to be more realistic with the acceleration and turning rate factors.

The results obtained from the model are intended to provide more quantitative information than the results of the regular models that are only interested in the survivability of the HVU. The result of each run is displayed in a comparative way on the simulation running window. Thus, the result of a scenario can be easily compared with another scenario by only clicking the information (wheel) button on the simulation running window.

All those properties are used as an initial approach to the future development of related OR topics. The modularity and scalability of the model enables the future analyst to extend his work from the DMM and develop the model into new areas.

B. RESULTS OF THE ANALYSIS

Based on extensive usage of regression methods, a comparative analysis approach was used throughout this study. With logistic regression methods, the MOE (percentage-hit on the HVU) is intended as a comparative mean for different scenarios.

The estimated regression equations were used to study the conditional effects of the range, bearing and the number of ship variables in the model. This approach was needed to see the effects of each variable in terms of damage criteria. The results show that more escort ships make a better defense of the convoy. However, the analysis has also showed that for small navies that could not afford more screen ships per HVU, positioning the escort ships within the threat sector provides an effective defense as well.

Having examined the defense load for each escort ship, the threat sector-positioning tactic also proved to be more effective. As more screen ships are placed within the threat sector, their defensive responsibility is reduced; thus they must deal with fewer incoming missiles, so the overall defense is more effective.

C. DEVELOPMENT OF DMM

Using DMM, the strengths and weaknesses of a few convoy formations were demonstrated as a preliminary analysis. The goal of this study was to provide a method for analyzing the effectiveness of these formations, but a definitive analysis would examine many more scenarios. By spending more effort on the model, new insights can be gained by the decision-maker.

The DMM uses the ASMD model in its simulation part. The ASMD model fully emulates the actual motion of missiles in space, with objects that accelerate and turn smoothly. The mathematical package, which features more sophisticated motion

parameters, can be easily utilized for future analysis to render moving objects even more accurately.

The DMM's GUI provides the user with such a user-friendly environment that even those who might not know the model can easily set a scenario and run the model. The GUI is designed to work only for defensive means and against, at most, two threats. But with the modularity and scalability features of the DMM, the model can support different scenarios with easy changes.

The features of ships are loaded from an INI file. This is adequate for little data. However, on the development of the new models, it is recommended that a database program be implemented. More effort, however, is required for database modification into the model using Java™ programming language.

D. ADAPTATION OF DMM IN THE TURKISH NAVY

This study must be regarded as only the first step toward enhancing the safety of the Turkish Naval Forces at sea. To manage this enhancement, the battlefield in DMM is designed as a littoral arena, resembling the Aegean and the Mediterranean Seas with many islands, isles, etc. The real maps were not intended to be used in this model for the unclassified scope of this study. But the real map usage could be easily adapted into this study by changing a few features of the model.

In adaptation process of this model into the Turkish Navy, the features to be employed (recommended) are as follows:

- More accurate and classified data.
- A new simulation model extended from the ASMD model is to be implemented in order to simulate the ASW, ASUW and Anti-Mine

Warfare. The ASMD model and the DMM's GUI are well suited to the planning and execution of these operations.

- The database usage instead of INI file property.
- The modification of the model in order to run in a network environment. This modification allows the model to have a real war game feature. For example, the model can be rewritten as a Java™ applet, which can be run in a browser, instead of an application, so blue and red sides can play in two different environments.

APPENDIX A. INI FILE INTERACTION IN DMM

A. INI FILES

Many applications written for Windows® have INI files which are used to store initialization data. Two examples from Windows® itself are win.ini and system.ini. DMM uses the INI file format as its primary configuration method. For example, a file called ships.ini, which is in the actions directory, is used to represent initialization data related with the HVU and the screen ships. An INI file is divided into sections. Part of the ships.ini file looks like this:

[GUIDE]

ship1 = **USS KITTY HAWK**
ship2 = **USS CONSTELLATION**
ship3 = **USS ENTERPRISE**
ship4 = **USS AMERICA**

[SCREEN SHIP CLASS]

class1 = **YAVUZ CLASS**
class2 = **KNOX CLASS**
class3 = **PERRY CLASS**
class4 = **SPRUANCE CLASS**

[USS KITTY HAWK]

hullno = CVN 63
speed = 32
aircraft = 85
crew = 5600
weapons = Sea Sparrow Phalanx
airradar = SPS 64
surradar = SPS 55

[YAVUZ CLASS]

ship1 = **TCG YAVUZ**
ship2 = **TCG YILDIRIM**
ship3 = **TCG TURGUTREIS**
ship4 = **TCG FATIH**

[TCG YILDIRIM]

hullno = F 243
speed = 27
crew = 200
SAM = Sea Sparrow Mk 29
gun = Sea Zenith
airradar = DA08
surradar = AWS 6 Dolphin

The INI files are divided into two sections: the part in the square brackets ([]) is defined as the “block” and each of the following lines separated by equals (=) gives a “keyname” and its setting, the “keyvalue.” Thus, in the block "GUIDE" the key value for the keyname ship1 is USS KITTY HAWK in the above example. In the ships.ini file, key values associated with ship’s names and ship’s classes appear to be the block names. By way of this structure, in the same file the very most detail of a ship can be reached.

B. READING FROM AN INI FILE

The goal in reading an INI file is to retrieve data stored therein. By having the keyname as the word to be looked up and the keyvalue as the definition of that word, it is possible to use an INI file as a glossary.

In ships.ini the blocks are designed to represent the names or the classes of the ships. If we need to know the names of YAVUZ class frigates (German made frigates in the Turkish Navy), we start to look up the block name [YAVUZ CLASS] and the keyvalues under that block name. In the same way, if we want to know the speed of TCG YILDIRIM (a YAVUZ class frigate), we need to find the block name with the same name [TCG YILDIRIM] and then the keyname, “speed”. The keyvalue “27” is the answer referring to the speed.

INIFileProperties class, written by Professor Arnold Buss, provides a mechanism to read the blocks and key/value pairs from an INI file. Since it extends java.util.Properties, anything can be done to it concerning the Properties objects. It uses the block names as keys for Hashtables of the key name/value pairs specified in each block.

1. Summary of Program

In a nutshell, the user is prompted to select an INI file. The load method is used to read the properties from an input stream and adds them to the properties list. The search for reading starts from the comments lines, which starts with “ # ” or “ ; ”, but the program skips those comments and starts directly from the lines starting with “ [“. After finding a line starting with “ [“ and ending with “] “ and appropriate keyvalues following this block, the block is put into a Property object and the keyvalues are put (fixed) into this block. Thus, the program, after finding the block [YAVUZ CLASS], relates every keyvalues under this block name (TCG YAVUZ, TCG YILDIRIM, TCG TURGUTREIS, and TCG FATIH) to the blockname as seen in Figure 29.

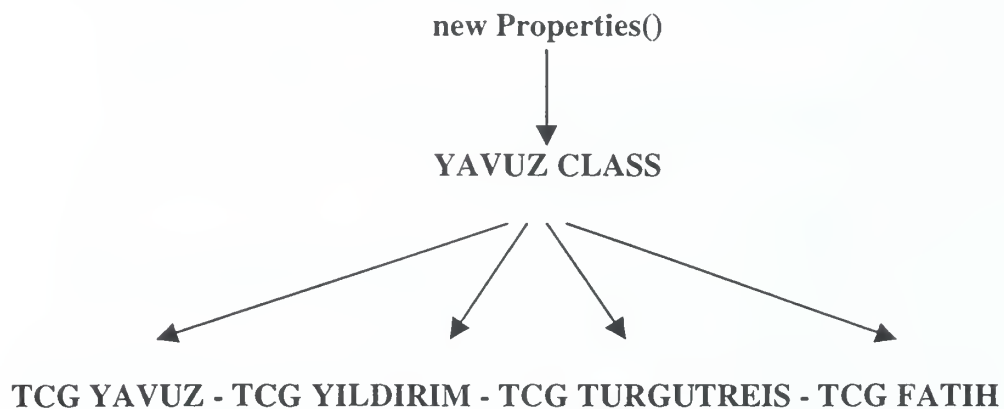


Figure 29. The INIFileProperties class, takes the block names and makes them objects of type Properties.

The other methods in the INIFileProperties class are mainly used to get the specific key values from the blocks or the blocks themselves.

2. Source Code

```
package actions;  
import java.io.*;  
import java.util.*;
```



```

public class INIFileProperties extends Properties {

    public void load(String filename) {
        filename.replace('\\', '/');
        int lineNumber = 0;
        try {
            FileReader instream = new FileReader(filename);
            BufferedReader input = new BufferedReader(instream);

            StringTokenizer tokens = null;
            Properties currentBlock = null;
            for (String nextLine = input.readLine(); nextLine != null; nextLine = input.readLine()) {
                lineNumber++;
                if (nextLine.startsWith(";") || nextLine.startsWith("#")) { }
                else if (nextLine.startsWith("[") && nextLine.endsWith("]")) {
                    tokens = new StringTokenizer(nextLine, "[ ]");
                    if (tokens.countTokens() == 1) {
                        currentBlock = new Properties();
                        this.put(tokens.nextToken(), currentBlock);
                    }
                    else {
                        throw new IllegalINIFormatException (
                            "Improper format in " + filename + " on line " + lineNumber + ":\n" +
                            nextLine);
                    }
                }
                else if (currentBlock != null) {
                    tokens = new StringTokenizer(nextLine, "=");

                    switch (tokens.countTokens()) {
                        case 0:
                            break;
                        case 1:
                            currentBlock.put(tokens.nextToken().trim(), "");
                            break;
                        case 2:
                            currentBlock.put(tokens.nextToken().trim(), tokens.nextToken().trim());
                            break;
                        default:
                            throw new IllegalINIFormatException (
                                "Improper format in " + filename + " on line " + lineNumber + ":\n" +
                                nextLine + "[# tokens = " + tokens.countTokens() + "]");
                    }
                }
            }
            input.close();
        }
        catch (FileNotFoundException e) {System.err.println(e); e.printStackTrace(System.err);}
        catch (IOException e) {System.err.println(e); e.printStackTrace(System.err);}
    }

    public Properties getProperties(String key) {
        return (Properties) this.get(key);
    }
}

```

```

public Object getINIProperty(String block, String key) {
    return getProperties(block).get(key);
}

public Object getINIProperty(String block, String key, Object defaultValue) {
    Object o = this.getINIProperty(block, key);
    return (o != null) ? o : defaultValue;
}

public String toString() {
    StringBuffer buf = new StringBuffer();
    Properties prop = null;
    for (Enumeration e = this.keys(); e.hasMoreElements(); ) {
        Object key = e.nextElement();
        buf.append("\n");
        buf.append("[");
        buf.append(key.toString());
        buf.append("]");
        buf.append("\n");
        try {
            prop = (Properties) this.get(key);
            for (Enumeration f = prop.keys(); f.hasMoreElements(); ) {
                Object key2 = f.nextElement();
                Object value2 = prop.get(key2);
                buf.append(key2.toString());
                buf.append(" = ");
                if (value2 != null){
                    buf.append(value2.toString());
                }
                buf.append("\n");
            }
        }
        catch (ClassCastException ex) {buf.append(this.get(key).toString());}
        catch (NullPointerException ex) {}
    }
    return buf.toString();
}

public String listBlocks() {
    StringBuffer buf = new StringBuffer();
    for (Enumeration e = this.keys(); e.hasMoreElements(); ) {
        buf.append(e.nextElement().toString());
        buf.append("\n");
    }
    return buf.toString();
}

public String specificValue(String blockName, String key) {
    return (String)getProperties(blockName).get(key);
}

public String getKey(String blockName, int index) {
    int i = 0;
    String str = " ";
    for (Enumeration e = getProperties(blockName).keys();e.hasMoreElements(); ) {
        Object en = e.nextElement();
    }
}

```

```

        if (i==index) {
            str = en.toString();
        }
        i++;
    }
    return str;
}

public static void main(String[] args) {
    INIFileProperties prop = new INIFileProperties();
    prop.load(args[0]);
    System.out.println(prop.listBlocks());
    System.out.println(prop.specificValue("USS NIMITZ", "speed"));
    System.out.println(prop.getKey("USS NIMITZ", 0));
}
}

```

APPENDIX B. ASMD MODEL

Combat in the ASMD model is conducted between entities at the Composite Unit level. A Composite Unit, for the purpose of the ASMD model, is a group of special purpose functional components that operate together. Using the premise of small reusable object programming, these composite units are created from several smaller components that seek to model the precise behaviors of the composite unit. A mover, for example, is created with some behaviors like movement, sensor capability and defensive factors (firing). The screen ships with more specific and particular behaviors are easily extended from this mover as a tactical unit. Missiles are also an extension of the mover element without having a defensive capability. The ASM sites are also movers with zero speed.

The main components of the Composite Unit are:

- Controller (two/three-dimension)
- Mover (two/three-dimension)
- Sensory Elements
- Firing Elements (interactor)

The interaction (communication) between composite unit elements is controlled by a referee component. The referee informs other components about runtime events such as a new missile fired from an ASM site or the direction and speed of a new composite unit.

The referee component tasks are:

- Register
- Mover Sensor Mediator
- Missile Target Mediator

These component elements will work together to model the Composite Unit as described below.

A. MAIN COMPONENTS

1. Controller (MoverBrain)

Every entity in the ASMD model has one common behavior: movement. The ships, missiles and even the ASM sites are all movers. An object called MoverBrain controls the movement of these entities.

MoverBrain is a relatively simple object that controls a mover object. It stores the list of destinations and times that the mover will traverse. Once the movement starts, it examines the movement capabilities of the mover and plans the best series of maneuver operations necessary to cause the Composite Unit to arrive at the next location at the correct time. MoverBrain dictates the turn rate, speed adjustments and the duration for these maneuvers to the mover.

Some of the entities, like ships, move to their destinations in two-dimension along the surface of the earth (2DMover) while some, like missiles, move in three-dimension (3DMover). The MoverBrain2D and MoverBrain3D make these adjustments accordingly. The MoverBrain3D, for example, directs a 3DMover at a certain rate and duration to change altitude.

2. Mover (FullMover)

Units like HVU and screen ships, ASM sites and missiles all extend from the mover object having an associated MoverBrain. An object called FullMover manages movement of a mover. Depending on the type of movement desired for the Composite Unit (two/three-dimension), FullMover2D and FullMover3D are used to accomplish it.

The movers are distinguished from each other by their name, initial location, speed, turn rate, acceleration rate and their two or three dimension behaviors. The FullMover is the storehouse for all the information. It responds to the orders of MoverBrain and provides a report regarding the current and next location, arrival time and duration of movement. It allows other components to know of the changes in direction, speed or altitude of a mover via the Referee, which will be discussed later.

Figure 28 summarizes the functions of both MoverBrain and FullMover.

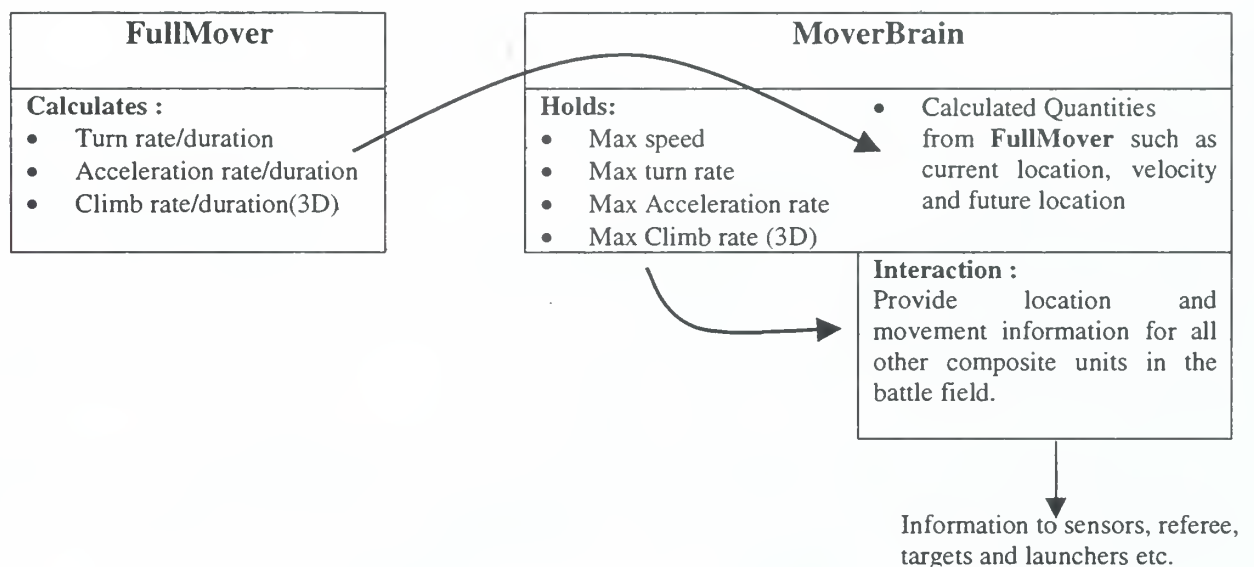


Figure 28. FullMover and MoverBrain Functionality

3. Sensors

Sensor objects provide sensing capability for the Composite Unit. Those objects are typically active radar systems employed onboard. Each sensor has parameters such as sensor range, target type (2D or 3D) that can be detected, the detection rate and the number of targets the sensor is capable of simultaneously tracking. Each composite unit might have more than one sensor with different parameters. The radars onboard a Yavuz (German made) class frigate are AWS-9, Decca and Dolphin for air, navigation and

tracking purposes respectively. In the DMM, all three are implemented to model a Yavuz class frigate as a screen ship.

The sensor broadcasts messages to the Referee and FireDistributor whenever it detects or loses a target. The sensor can be changed from “on” to “off” or vice-versa. The sensor also informs the Referee about this behavior. Figure 29 illustrates the functionality of sensor elements.

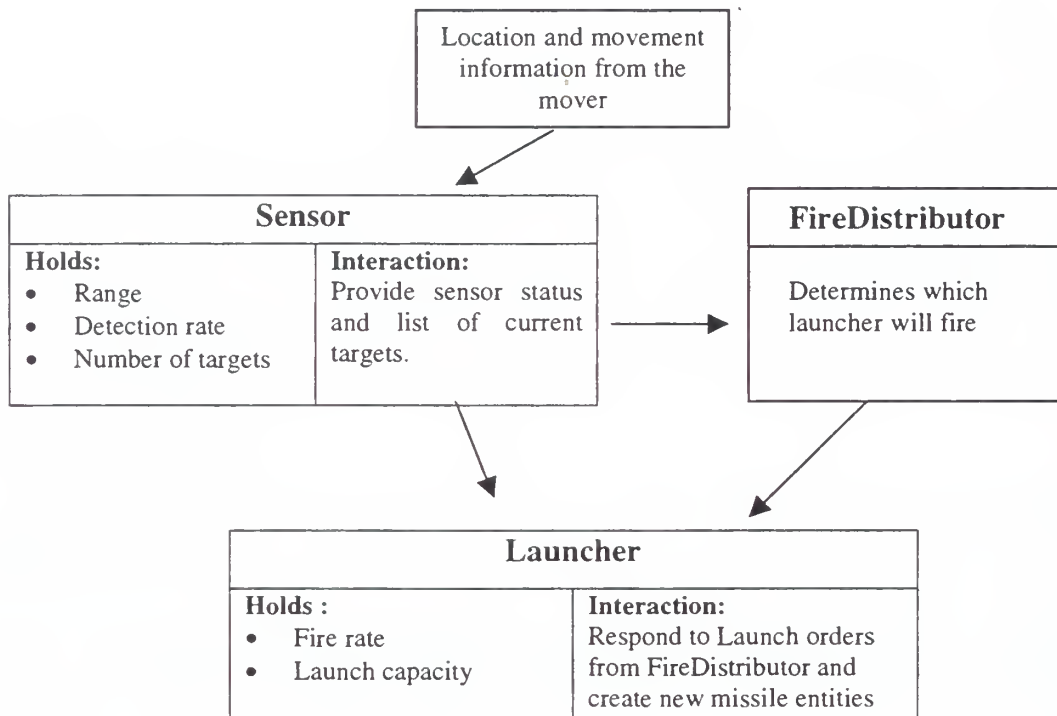


Figure 29. Sensor and Launcher Functionality

4. Firing Element

Launcher objects provide the Composite Unit with the firing capability. This behavior performs the defensive actions for the screen. Each launcher possesses properties that control the launch rate quantity and types of missiles that can be launched. The launcher responds to orders from the FireDistributor.

The FireDistributor performs the decision logic necessary to allocate fire against enemy forces. The convoy has one FireDistributor which coordinates AAW firing against each ASM. ASM sites have also one FireDistributor which allocates ASM attacks. Whenever a sensor detects a new target, it informs the FireDistributor. It is then the FireDistributor's mission to allocate an appropriate weapon against this new target. It makes the necessary calculations to know which system can intercept the target first. The FireDistributor is a kind of MoverBrain, but for launcher objects (Figure 29).

B. REFEREE COMPONENT

Every war game needs an unallied, honest broker in the battlefield that resolves issues between opponents. As the name implies, Referee provides the necessary components that resolve issues among movers, sensors and their targets. Register, for example, is the component that reacts to the addition of a new Composite Unit (a new missile) and creates a Mediator between the missile and its target. The MoverSensorMediator adjudicates the interaction between a moving target and a sensor evaluating when and if the mediated target becomes detected or remains undetected by the mediated sensor. MissileTargetMediator is another component that adjudicates the interaction between missiles that are homing against a target. The mediator listens to the movements of the target and directs the missile to adjust its flight for interception with the target.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

1. Macfadzean, Robert H. M., *Surface-Based Air Defense System Analysis*, Artech House, 1992.
2. Law, Averill M. and D. W. Kelton, *Simulation Modeling And Analysis*, McGraw-Hill, Inc., 1991.
3. Brooks, A., S. Bankes, and B. Bennett, *Weapon Mix And Exploratory Analysis*, Rand Corp., 1993.
4. Hughes, Wayne P. Jr., Captain, U.S.Navy (Retired), *Fleet Tactics And Coastal Combat*, Naval Institute Press, 1999.
5. Morse, Philip M., and G. E. Kimball, *Methods of Operations Research*, Technology Press, MIT, 1952.
6. Hughes, Wayne P. Jr., Captain, U.S.Navy (Retired), *Fleet Tactics Theory and Practice*, Naval Institute Press, 1986.
7. Wade, John F.G., *Navy Tactics, Doctrines, and Training, And Training Requirements for Littoral Warfare*, Master's Thesis, Naval Postgraduate School Monterey, CA., 1996.
8. Arnzen, A., *Software Components for Air Defense Planning*, Master's Thesis, Naval Postgraduate School Monterey, CA, 1998.
9. Buss, A.H. and K. Stork, "*SIMKIT User's Manual*", Naval Postgraduate School, Monterey, CA, 1998.
10. Townsend, James R., *Defense of Naval Task Forces From Anti-Ship Missile Attack*, Naval Postgraduate School, 1999.
11. Geary, David M., *Graphic Java™ Swing Mastering The JFC*, Sun Microsystems Press, 1999.
12. Geary, David M., *Graphic Java™ AWT Mastering The JFC*, Sun Microsystems Press, 1999.
13. Hamilton, Lawrence C., *Regression with Graphics*, R.R. Donnelley & Sons Company, 1992.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center 2
8725 John J. Kingman Rd., STE 0944
Ft. Belvoir, Virginia 22060-6218
2. Dudley Knox Library 2
Naval Postgraduate School
411 Dyer Rd.
Monterey, CA 93943-5101
3. Deniz Kuvvetleri Komutanligi 2
Personel Daire Baskanligi
Bakanliklar - 06100
Ankara, TURKEY
4. Deniz Kuvvetleri Komutanligi 1
Kutuphanesi
Bakanliklar - 06100
Ankara, TURKEY
5. Deniz Harp Okulu 1
Kutuphanesi
Tuzla
Istanbul, TURKEY
6. Military Operations Research Society (MORS)..... 1
101 S.Whiting Street
Suite 202
Alexandria, VA 22304-3416

7. Chairman, Code 30 (OR/Rl)..... 1
Naval Postgraduate School
Monterey, CA 93943-5100
8. Prof. Arnold H. BUSS (OR/Bu)..... 1
Department of Operations Research
Naval Postgraduate School
Monterey, CA 93943-5101
9. LCDR Douglas J. MACKINNON (OR/Mg)..... 1
Department of Operations Research
Naval Postgraduate School
Monterey, CA 93943-5101
10. Yazilim Gelistirme Grup Baskanligi..... 1
Deniz Harp Okulu Komutanligi
Tuzla
Istanbul, TURKEY
11. LTJG. Erhan AYDIN 2
Ataturk Caddesi, Erenler Sitesi
A Blok Daire 6
Erenkoy
Istanbul, TURKEY

63 290NP6
TH 2577
6/02 22527-200 NLE



DUDLEY KNOX LIBRARY



3 2768 00402774 8